Interventions and Outcome Measures for Occupational Hearing Loss: Two Scoping Reviews

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Audiology

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University of Canterbury

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2018

Contents

Acknowledgements

I'd like to extend my sincere thanks to Dr Rebecca Kelly-Campbell for all her hard work supervising this project. Dr Kelly-Campbell's door was always open whenever I ran into trouble or had a question regarding my research. She allowed this project to be my own work but steered me in the right direction whenever I needed it. Without her help this project would not have been possible.

I would also like to thank Dr Kim Wise for all her support both in getting this project off the ground and for providing much needed feedback on my writing.

I'd like to thank my friends and family for their love and support during my studies.

Lastly, thank you Angelina for being my rock.

Abstract

Noise-induced hearing loss (NIHL) is the second-most common form of hearing loss in the world. Many cases of NIHL occur within an occupational setting. Occupational hearing loss (OHL) is considered to be preventable, provided appropriate intervention strategies are employed. A scoping review was performed to discover intervention strategies for OHL discussed in the literature, and to identify common themes about their usage. A second scoping review was performed to identify appropriate outcome measures that can be used in future projects to assess the efficacy of interventional strategies. Commonly used intervention strategies included the use of hearing protection devices (HPD), the implementation of comprehensive hearing conservation programmes (HCP), administrative control strategies, audiometric monitoring, engineering control strategies, educational programmes, legislative control and pharmacological otoprotective drugs. Outcome measures used in OHL research included audiometric threshold shifts, level of noise exposure, HPD usage, number of incidences of OHL, changes in otoacoustic emissions, self-reported hearing loss complaints, tinnitus, attitudes and believes towards hearing loss prevention, prevalence of occupational injuries, number of OHL compensation claims lodged, blood pressure, number of falls in seniors, hyperacusis, occupational difficulties, changes in preventative actions undertaken, sources of income and work readiness.

Abbreviations

AAT – Acute acoustic trauma

ACC – Accident Compensation Commission

ADL – Activities of Daily Living scale

CESPA – French Armed Forces Centre for Epidemiology and Public Health

CI – Cochlear implant

(CINHL) – Cumulative Index to Nursing and Allied Health Literature

dB - DeciBel

DPOAE – Distortion product otoacoustic emission

EAM – External auditory meatus

FM – Frequency-modulated

GDP – Gross domestic product

HAT – Hearing assistive technology

HL – Hearing level

HPD – Hearing protection device

Hz - Hertz

IHC – Inner hair cells

MET – Mechanoelectric transmission

NIHL – Noise-induced hearing loss

NIOSH – National Institute of Occupational Safety and Health

OHC – Outer hair cells

OHL – Occupational hearing loss

ONIHL – Occupational noise-induced hearing loss

PICO – Population, Intervention, Comparison, Outcome

PPC – Population, Concept, Context

PTA – Pure-tone audiometry

PTS – Permanent threshold shift

RNIHL – Recreational noise-induced hearing loss

ROS – Reactive oxygen species

SPIN – Speech Perception in Noise test

TM – Tympanic membrane

TTS – Temporary threshold shift

USA – United States of America

VSL – Value of statistical life

WHO – World Health Organisation

1.0 Introduction

1.1 Hearing Loss

Hearing loss is defined as the complete or partial inability to hear sound (Atcherson, 2013). Its effects can be temporary or permanent in nature and either sudden or gradual in onset (Imam & Hannan, 2017). Hearing loss can affect an individual's hearing unilaterally or bilaterally, whilst the severity of the loss can vary greatly from person to person (Madgaonkar, 2011).

Hearing loss can be the result of many different factors. Genetic predisposition or perinatal complications can result in a congenital hearing loss present from birth (Smith, Shearer, Hildebrand, & Van Camp, 2014), whilst acquired forms of hearing loss due to illness, injury, the ageing process, or environmental factors may occur at any stage of life (Mills & Going, 1982).

Regardless of its cause or the time of its onset, hearing loss can have a severe impact on interpersonal communication, psychosocial wellbeing, economic independence and quality of life (Olusanya, Neumann, & Saunders, 2014). The World Health Organisation (WHO) estimates that over 5% of the world's population (360 million people) currently live with disabling hearing loss, which they define as a loss greater than 40dB HL in the individual's better-hearing ear (World health Organisation, 2017).

Exeter, Wu, Lee, and Searchfield (2015) have estimated that the number of New Zealanders affected by hearing loss will grow by 119,184 by the year 2061. This necessitates not only an increase in the availability of hearing health services in New Zealand (Exeter et al., 2015), but an improvement in the strategies currently implemented to reduce the prevalence of preventable types of hearing loss such as those caused by noise exposure (Thorne et al., 2008).

1.2 Anatomy of the Auditory System

The human auditory system consists of multiple structures. These structures collect sound from the environment and transduce it into nervous impulses. These impulses are then transferred to the auditory centres of the brain and interpreted as sound (Alberti, 2001; Ferris & Prendergast, 2000). The perception of sound is integrated with input from other sensory systems to provide the listener with information about their environment (Stein, Stanford, & Rowland, 2009). The auditory system is traditionally divided into several different sections. Each section contains structures responsible for a different part of the transduction process (Zwicker & Fastl, 2013).

1.2.1 The outer ear

The pinna, also known as the auricle is the visible part of the ear. The pinnae are located over the temporal bones on each side of the head (Miller & Keane, 1983). The pinna consists of a series of elastic cartilaginous folds designed to collect, amplify and filter sounds arriving at the ears (Wilson, 1851). Some sounds enter the ear canal directly, while others are first reflected off the folds of the pinna. This creates spectral cues that aid the localisation of sound in the vertical plane (Hofman & Van Opstal, 2003; Purves et al., 2001).

After being focused and filtered by the pinna sound enters the external auditory meatus (EAM) (Purves et al., 2001). The EAM is a thin tube extending roughly 2.5cm into the head of an adult ending at the tympanic membrane (TM) (Reynolds, 2004).

The EAM acts as an amplifier in two ways. The difference between the size of the pinna and the size of the EAM increases the sound pressure level much like how placing a thumb over the end of a hose increases water pressure (Alberti, 2001). The resonation of soundwaves within the EAM causes further amplification. The resonant frequency of a human EAM is between 2.5

kHz and 3 kHz (Couto & Carvallo, 2009; Purves et al., 2001; Silva, Blasca, Lauris, & Oliveira, 2014). This increases the sensitivity of human hearing around this frequency range, explaining why humans are particularly susceptibility to acoustic damage within this frequency band (Purves et al., 2001).

As sound reaches the end of the EAM it strikes the TM. The TM is a cone shaped membrane consisting of a combination of skin, fibrous tissue and mucosa ("Tympanic Membrane," 2016). The TM acts as a barrier between the outer and middle sections of the ear (Alberti, 2001). When soundwaves impact the TM it vibrates sympathetically transferring the sound energy to the ossicular chain (Bergevin & Olson, 2014).

1.2.2 The middle ear

The ossicular chain refers to a series of small bones located in the middle ear cavity (Ferris & Prendergast, 2000). These bones are collectively known as the ossicles. The first ossicle, known as the malleus, is connected to the TM (Alberti, 2001; Gray, 1878). As the TM vibrates the malleus moves in tandem. The motion of the malleus is transferred to the incus and then the stapes through the articulation of associated joints. The vibrations are then passed into the liquid-filled cochlea through pressure being applied to a membranous window (Alberti, 2001; Ferris & Prendergast, 2000).

The ossicles provide a mechanical advantage to the movement of the TM (Guelke & Keen, 1952; Howarth & Shone, 2006). They act as a mechanical lever trading off the displacement of the TM for an increase in pressure at the cochlea. This reduces in the distribution of the force further intensifying the vibration (Howarth & Shone, 2006; Quam, Coleman, & Martínez, 2014). This function helps to overcome the difference in impedance between the outside air and the liquid-filled cavities of the cochlea (Merchant, Ravicz, &

Rosowski, 1996). A compromised ossicular chain can cause a person's hearing to deteriorate by up-to 50 dB HL across all frequencies (Farahmand et al., 2016).

1.2.3 The inner ear

The cochlea is located within the inner ear (Ekdale, 2016). The cochlea consists of a bony spiral-shaped shell containing three liquid filled cavities (Alberti, 2001). The basal end of the cochlea protrudes into the middle ear cavity (Gray, 1878). The footplate of the stapes is connected to the liquid filled Scala Vestibuli via the membranous oval window (Alberti, 2001; Thompson, Ohazama, Sharpe, & Tucker, 2012).

The movement of the stapes displaces the fluid within the Scala Vestibuli, which in turn causes vibrations along the basilar membrane. These vibrations cause the deflection of stereocilia hair cells arranged tonotopically along the basilar membrane (Ekdale, 2016; Von Békésy & Wever, 1960).

Owing to changes in the stiffness and mass of the membrane along its length, the vibrations resonate at locations that are related to their frequency (Purves et al., 2001; Von Békésy & Wever, 1960). This causes the maximum deflection of stereocilia to occur at the point of resonance, effectively dividing sounds into their component frequencies (Purves et al., 2001).

The deflection of these hair cells causes mechanoelectrical transmission (MET) channels within the hair cells to open (Fettiplace & Hackney, 2006; Flock, 1964; Hudspeth, 1989). This leads to a change in voltage within the cell which produces action potentials within afferent neurons (Qing & Mao-Li, 2009). These nervous impulses then flow up the ascending auditory pathway to the auditory cortex of the brain (Alberti, 2001).

1.3 Types of Hearing Loss

Hearing loss can occur due to a problem with the transmission of sound in any part of the auditory system (Dobie & Van Hemel, 2005). If the outer and middle ear are not functioning correctly the hearing loss is termed to be conductive in nature (Anthwal & Thompson, 2015). This name alludes to the problem being due to irregularities in the transmission of sound to the inner ear. Conductive hearing losses are often caused by malformations or blockage of the outer ear, liquid in the middle ear cavity obstructing the movement of the TM and the ossicles, or damage to the ossicular chain (Zahnert, 2011). Conductive hearing losses are often transient in nature and can usually be treated by medical or surgical intervention (Isaacson & Vora, 2003).

If a hearing loss is caused by damage or malformation of the inner ear or neural pathways from the cochlea to the brain it is defined as a sensorineural hearing loss (Zahnert, 2011). Sensorineural losses are often caused by the death of stereocilia within the cochlea. The body is unable to replace these cells if they are destroyed (Kuhn, Heman-Ackah, Shaikh, & Roehm, 2011). The death of stereocilia causes a reduction in hearing sensitivity at the frequencies of sound that the damaged stereocilia are designed to transmit (Raphael, 2002). Additionally, this reduces the specificity of the tonotopic map within the cochlea and causes the tuning of the individual’s hearing to broaden. Broadening of tuning adds an element of distortion to the perception of sound and decreases intelligibility (Dubno & Dirks, 1989; Glasberg & Moore, 1986; Tyler, Hall, Glasberg, Moore, & Patterson, 1984).

Sensorineural hearing losses are said to be permanent in nature as damage is unable to be repaired with current technology or medicine (Zahnert, 2011). Sensorineural hearing losses are largely caused by overexposure to loud sounds and the aging process, but can also be caused by disease, congenital issues and impact damage (World health Organisation, 2017; Zahnert, 2011).

If a hearing loss consists of both a sensorineural and a conductive component it is said to be a mixed hearing loss (Gillam, Marquardt, & Martin, 2010; Verhaert, Desloovere, & Wouters, 2013). In the case of a mixed loss it may be possible for the conductive component of the hearing loss to be alleviated, thereby improving the individuals hearing thresholds. However, the sensorineural damage to the underlying hearing cannot be repaired.

1.4 Effects of Hearing Loss

Strawbridge, Wallhagen, Shema, and Kaplan (2000) studied the hearing loss by dividing its effects among three categories. (1) Physical function (2) mental health (3) social function.

1.4.1 Physical auditory function

Individuals with a hearing loss often have difficulty localising sound compared to those who have hearing within normal limits. Byrne, Noble, and Ter-Horst (1995) showed that when assessed using a questionnaire regarding localisation of sound participants with hearing loss rated their ability to localise sound consistently lower than the normal hearing control group. Noble, Byrne, and Lepage (1994) showed that this deficiency was present regardless of the type of hearing loss; however those with conductive or mixed hearing losses displayed a greater deficit in localisational ability than those with a purely sensorineural loss.

Localisation of sound plays an important role in physical safety in an urban environment. For example, it is important to be able to locate a person who calls out, or determine where a vehicle is coming from when crossing the road (Byrne & Noble, 1998). Safety is not the only important aspect to localisation. Killion (1997) explained that localisation is an important part of the aesthetic experience. Humans want to be able to locate a singing bird or a rustling bush regardless of whether it constitutes a threat. The lack of this ability can cause an individual to feel out of place or disconnected from reality.

Hirsh (1950) found evidence that lack of localisation clues diminishes the ability of an individual with hearing loss to understand speech in a noisy environment. A later study by Noble, Byrne, and Ter-Horst (1997) found only a weak correlation between localisation and speech in noise, suggesting that more research into the area is required.

Regardless of whether a loss of localisation is the primary reason, it is well-recognised that hearing loss causes difficulty understanding speech in background noise. Dubno, Dirks, and Morgan (1984) showed that individuals with a mild sensorineural hearing loss performed significantly worse than their counterparts with normal hearing when tested using the Speech Perception in Noise (SPIN) test (Kalikow, Stevens, & Elliott, 1977). Hsieh, Lin, Ho, and Liu (2009) displayed that this is also true of conductive pathologies. Furthermore, many studies have consistently shown that an inability to understand speech in background noise is a major complaint of hearing aid users (Kochkin, 1992, 1993, 1995, 2002). This suggests that difficulty understanding speech in noise is a common symptom of all types of hearing loss.

Hearing loss causes sound to appear muffled, and can give the sensation that the individual’s ears are blocked (OiSaeng Hong, Kerr, Poling, & Dhar, 2013). The exact perceptual changes are dependent on the configuration of the individual’s hearing. An individual with a high-frequency sensorineural hearing loss is likely to find speech and sound lacking in clarity (Turner & Per-Lee, 1990). However, individuals with a low-frequency hearing loss more often describe a lack of overall volume and a tinny quality to sound (Westcott, 2015). Regardless of the configuration, this change in the balance of sound can cause adverse effects to speech intelligibility (Figueiredo, Mendes, Cavanaugh, & Novaes, 2016).

Apart from these primary symptoms, hearing loss can cause several secondary symptoms. Hyperacusis or a collapsed tolerance for loud sounds is a common complaint among those with a sensorineural hearing loss (Baguley, 2003). This is often (but not universally) caused by loudness recruitment. Loudness recruitment is caused by damage to the compressive element of the cochlea (Moore, 2012). An individual with recruitment may find that sound progresses from too quiet to hear, to too loud to tolerate over a reduced dynamic range compared to a person with normal hearing (Eisenberg, 1958; Moore, 2012).

Tinnitus is defined as sound sensation in the ears (often described as ringing or buzzing) that is not being generated externally (Jastreboff, 1990). As with hearing loss, tinnitus can vary from mild to severe (Axelsson & Ringdahl, 1989), and can have a severe effect on the mental health of the individual (Lynn et al., 2003; Malakouti, Mahmoudian, Alifattahi, & Salehi, 2011; Scott & Lindberg, 2000; Unterrainer, Greimel, Leibetseder, & Koller, 2003). Although the exact cause of tinnitus is disputed (Henry, Roberts, Caspary, Theodoroff, & Salvi, 2014) tinnitus is a common complaint amongst those with noise-induced hearing loss (NIHL) (Flores, Teixeira, Rosito, Seimetz, & Dall'Igna, 2016; T. N. Le, L. V. Straatman, J. Lea, & B. Westerberg, 2017).

1.4.2 Mental health

In addition to functional symptoms, hearing loss can lead to a decline in the mental health of the effected individual. In a review of the historical literature Jakes (1988) concluded that hearing loss causes emotional disturbances of more than a transient nature. He further showed that these disturbances were relieved when the hearing loss was rehabilitated. Tambs (2004) showed that hearing loss has a moderate effect on self-reported ratings of anxiety, depression, self-esteem and wellbeing amongst a normal population of 50,398 adults (aged 20 years and above).

Kvam, Loeb, and Tambs (2007) analysed the responses of self-described deaf individuals as compared to hearing individuals on two postal surveys conducted in Scandinavia using the Hopkins Symptom Checklist (Parloff, Kelman, & Frank, 1954), to determine levels of mental distress. This study concluded that the deaf respondents showed considerably greater levels of mental health problems than individuals with normal hearing.

Several studies have also reported an association between hearing loss, the development of dementia, and loss of cognitive function in later life (Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011; Uhlmann, Larson, Rees, Koepsell, & Duckert, 1989).

1.4.3 Social Function

An activity limitation is defined as “a difficulty encountered by an individual in executing a task or action”. A participation restriction is defined as “a problem experienced by an individual in involvement in life situations” (World Health Organization, 2002, para 1). Helvik et al. (2006) showed that in a group of 343 adult clients from a Norwegian university hospital those participants who had not yet undergone rehabilitation (in the form of hearing aids) for their hearing loss, displayed greater activity limitations and participation restrictions than those who were already experienced in hearing aid use. Gopinath et al. (2012) assessed the activity limitations of a group of 1,952 adults aged 60 years and above, using the activities of daily living (ADL) scale and pure-tone audiometry (PTA). The researchers concluded that ADL scale scores are diminished by hearing impairment, and that this could mean the difference between an individual’s independence and need of support services. Dalton et al. (2003) reported that the activity limitations and participation restrictions associated with hearing loss have a significant impact on quality of life.

1.4.4 Third-Party Disability

Hickson and Scarinci (2007) explained that the effects of hearing loss do not occur in a vacuum. Individual's with a hearing loss do not live in isolation, and the effects a hearing loss has upon communication are also felt by their significant others, family and friends. In this context, the hearing loss can be viewed as an environmental factor that causes activity limitations and participation restrictions for normal-hearing parties (Hickson & Scarinci, 2007).

People who are in denial about their hearing loss often cause conflict within the family unit (Armero, 2001). Lormore and Stephens (1994) performed a study on the common difficulties faced by adults with hearing loss and their spouses. One hundred and twenty-one hearing-impaired individuals and their partners answered an open-ended questionnaire and the differences between their responses were analysed. The researchers found subtle differences between the two groups, and noted that emotional responses to the questions were more common amongst the spouses than the individuals with a hearing loss.

A study by Hallberg (1995) into the effects of hearing loss on family dynamics in Sweden showed hearing loss to have a negative impact on the intimate relationships of couples. This was often due to the partner with a hearing loss demonstrating a refusal to acknowledge that they have a problem. A follow-up study by Hallberg and Barrenäs (1993) aimed to describe the experience of living with a male with hearing loss from the perspective of the spouse. The researchers found reluctance to acknowledge hearing difficulties and the impact that hearing loss has upon the couple's intimate relationship to be two, major reoccurring themes. The researchers suggested that the way the spouse reacts to this influences the outcome of any rehabilitative efforts, and therefore spouses should be included in every part of the rehabilitation process.

Hickson, Scarinci and Worrall showed in a series of studies (2008, 2009a, 2009b) that third-party disability effects nearly every facet of a spouse's life. The need to adapt to their partner's hearing in every situation causes difficulties ranging from general communication problems, to problems performing everyday tasks and activities, and broader effects upon martial harmony and social interactions.

1.4 Rehabilitation of Hearing Loss

Humans have been attempting to treat or mitigate the effects of hearing loss for centuries. Reports of treatments for hearing difficulties can be traced back as far as ancient Egyptian (Ebbell, 1937) and Hindu scriptures (Savithri, 1988). Modern approaches to permanent hearing loss rehabilitation primarily focus upon a combination of technology to mitigate some of the difficulties encountered with hearing loss (Mills, 2011), and counseling techniques to help the listener make better use of their residual hearing (Saunders & Forsline, 2012).

1.4.2 Hearing aids

Hearing aids provide a way of allowing the listener to use their residual hearing more efficiently (Gillam, Marquardt, & Martin, 2010). The operation of modern hearing aids can be simplified into three steps. (1) Microphones collect sound from the surrounding environment. (2) The signal is modified to maximise its utility to the listener accounting for the severity and configuration of the users hearing loss, the type of environment they are listening in, and the type of signal they want to focus on. (3) The adjusted signal is reproduced in the user's ear via the receiver (speaker) (Bento & Penteado, 2010; Dillion, 2012; Kulkarni & Hartley, 2008; Schaub, 2008).

The signal processing stage of modern hearing aids is performed digitally (Levitt, 2006, 2007). This provides greater flexibility and allows hearing aids to incorporate additional features. Digital processing allows for “smart” hearing aids that can adapt to the listener’s environment (Dillion, 2012; Kulkarni & Hartley, 2008; Levitt, 1987, 2007).

A hearing aid may be designed to operate through the user’s air conduction pathway, or by transmitting sound directly to the inner ear via bone conduction (Hagr, 2007; Hakansson, Tjellstrom, Rosenhall, & Carlsson, 1985). Bone conduction hearing aids are particularly effective in cases of conductive hearing loss, as they bypass the outer and middle ear (Hagr, 2007; Mylanus, van der Pouw, Snik, & Cremers, 1998).

Implantable devices offer advantages over traditional hearing aid solutions for certain types of hearing loss (Chasin, 1997). Although bone conduction hearing aids can be attached via a headband, the impedance of the skin reduces the amount of usable gain that can be offered. Bone-anchored hearing aids provide a way to get around this (Chasin, 1997). The transducer is able to be directly attached to the temporal bone via a surgically implanted abutment reducing impedance and allowing for an increased fitting range. In addition better stabilisation of the device is able to be achieved than with a headband (Dillion, 2012).

An alternative style of implant used to stimulate the cochlea directly is the middle ear implant. This type of implant works as a replacement for the middle ear (Haynes, Young, Wanna, & Glasscock, 2009). A vibrating transducer is attached directly to the oval window of the cochlea, or to the incus and is stimulated by a sound processor (Katz, Medwetsky, Burkard, & Hood, 2009). Middle ear implants are often used in situations where there is a problem with the ossicular chain (Haynes et al., 2009).

In cases where the integrity of an individual's cochlea is compromised, a cochlear implant (CI) can be used to treat resultant hearing loss. A CI consists of 2, main components. The first being an array of electrodes implanted directly into the cochlea itself, while the second is a sound processor positioned over the temporal bone and connected to the implant via an imbedded magnet. Sound is collected by the processor and used to stimulate the auditory nerve in place of the cochlea, by turning different electrodes within the array on or off (Katz et al., 2009).

1.4.3 Other rehabilitative strategies

In addition to hearing aids, other rehabilitative strategies may be employed to help mitigate the impact of hearing loss. Sign language, or an abridged form of visual language can be used in addition to oral and written language to improve communication. This is often part of a total communication approach, where the user is encouraged to use any combination of communication modalities that allow them to communicate effectively (Evans, 1982; McFadden, 1999). Sisson and Barrett (1984) have shown the superiority of a total communication approach in facilitating sentence repetition in children with hearing loss. A longitudinal study conducted by Delaney, Stuckless, and Walter (1984) showed that the communication skills and academic achievement of students from a school of the deaf improved significantly over a 10-year period after a total communication approach was introduced. However, because of other confounding, significant changes to the school environment over this period, the researchers were not able to be certain how much of this improvement was due to the new approach to communication.

For a visual language to be employed both participants in the conversation must be familiar with the signs involved. In lieu of this, simpler communication strategies may be employed to improve the communication environment (Trotter, Matt, & Wojnara, 2014). These strategies may involve counselling the individual to use their surroundings to their advantage when in conversation (Tye-Murray & Witt, 1997). For example, by ensuring that their conversation partner is not backlit during the conversation the listener improves their ability to see non-verbal cues such as body language and lip movement (Newton & Shah, 2013).

Individuals with a hearing loss are often advised to let their conversation partners know that they are hard-of-hearing. This enables their communication partner to adjust the delivery of their message to better favour the recipient (Newton & Shah, 2013; Tye-Murray & Witt, 1997).

Communication repair strategies can be employed in case of a breakdown in communication. These strategies may take the form of asking the communication partner to reiterate, rephrase or elaborate on their message (Brinton, Fujiki, Loeb, & Winkler, 1986; Gibson & Caissie, 1994; Tye-Murray & Witt, 1997). Tye-Murray, Purdy, Woodworth, and Tyler (1990) showed that the use of communication repair strategies enhance a listener’s ability to lipread a misperceived sentence irrespective of the type of strategy employed.

Trotter et al. (2014) surveyed 32 health care professionals with hearing loss and found that all 32 utilized communication strategies to better-communicate with their patients. The study concluded that these strategies were effective and the health care practitioners felt that they could communicate effectively with their patients most of the time.

Hearing assistive technology (HAT) devices are broadly-defined as any device that enables the user to better interact with the auditory world (Jorgensen & Messersmith, 2015). Examples of these devices include tactile alarms, amplified phones and frequency-modulated (FM) systems (Chisolm, Noe, McArdle, & Abrams, 2007). These devices may be used in addition to, or as an alternative to hearing aids or other strategies.

1.4.4 Counselling

Counselling is an important component of any rehabilitative strategy (Blood, 1997). Sanders (1975) described counselling in an audiological setting as being a combination of informational counselling and personal adjustment counselling.

Informational counselling (also known as content counselling) can be defined as the presentation of facts about hearing loss and its consequences, and the rehabilitation strategies that can be employed to mitigate its effects (Flahive & White, 1981). Personal adjustment counselling aims to help the individual modify any negative emotions caused by their hearing loss. This approach can be used to address emotions such as anxiety, vulnerability and depression (English, 2000).

Both these approaches to counselling combine to form part of a client-centred approach to clinical practice. The client-centred approach has been shown by Little et al. (2001) and Oates, Weston, and Jordan (2000) to provide better health-related outcomes than a provider-driven approach (Saunders & Forsline, 2012). Hawkins (2005) showed that a counselling-based rehabilitation programme has the potential to reduce an individual's hearing handicap while increasing their usage of communication strategies and hearing aids. These outcomes are highly dependent on factors such as the personality of the client, their rapport with the counsellor and the content of the programme (Trybus, Stika, & Goulder, 1997)

1.5 Societal Costs of Hearing Loss in New Zealand

Hearing loss causes a significant financial cost to society (Mohr et al., 2000). A report compiled by Deloitte Access Economics (2017), on behalf of the New Zealand Foundation of the Deaf, revealed that hearing loss costs New Zealand an estimate of $4.9 billion per annum. Nine-hundred and fifty-seven million dollars of this figure can be attributed to direct financial costs to the New Zealand tax payer. The remaining $3.9 billion is due to loss of wellbeing of the effected individuals, accounting for the value of statistical life (VSL) lost due to reduced health and premature mortality. Value of statistical life can be defined as the estimated monetary value society places on an anonymous life (Deloitte Access Economics, 2017).

1.5.1 Health system costs

Hearing loss costs the New Zealand health system an estimated $131.8 million per annum. The largest proportion of this amount is spent on services that are provided outside of the public health system. This includes the services of private audiologists, audiometrists and other health professionals. Non-admitted hospital expenditure and out-of-hospital medical services are the next most significant expenses totaling $17.8 million and $16.6 million respectively. The New Zealand government contributed 83.2% of the total cost to the health system whilst the remaining 16.8% was funded privately by individuals, insurers and charities (Deloitte Access Economics, 2017).

1.5.2 Productivity and efficiency

Loss of productivity due to hearing loss was estimated to have a cost of $552.4 million per annum (Deloitte Access Economics, 2017). This loss is mainly attributed to the impact a hearing loss has upon an individual's chances of finding and keeping employment. Jensen et al. (2005) showed that 63% of the working aged population with a hearing loss is in full time or part time employment in New Zealand compared to 73% of working aged individuals with normal hearing.

Productivity can be described as the quantity of production being achieve per unit of input, whilst efficiency can be described as the quality of production (Roghanian, Rasli, &

Gheysari, 2012). The Deloitte Access Economics (2017) report found reduced efficiency of production due to hearing loss costs New Zealand $77.2 million per annum. The remaining $95.5 million per annum consisted of costs associated with providing special telecommunication services, help with childcare, education services including sign language support for schools and interpreters.

1.5.3 Transfer payments

Transfer payments can be defined as a shift of financial resources from one economic entity to another without any goods or services being expected in return (2007). The total transfer costs absorbed by the New Zealand government due to hearing loss were estimated to be $386 million in 2016. This figure includes $109.6 million in costs to the health system, $254.6 million of lost potential tax revenue due to reduced employment, $149 million in welfare payments to those unable to support themselves due to their hearing loss, and $6.8 million in other governmental programmes and initiatives (Deloitte Access Economics, 2017).

1.6 Societal Costs Internationally

A similar report conducted in Australia found the total financial cost of hearing loss of 11,748 million Australian dollars in 2006. This amounts to 1.39% of the total Australian gross domestic product (GDP) for 2006 (Deloitte Access Economics). Mohr et al. (2000) showed that hearing loss acquired in 1998 could be expected to cost the United States economy $4.6 billion over the collective lifetime of the effected individuals. The majority of this total being due to reduced work productivity, and the cost of educational support.

1.7 Financial Costs to the Individual

On an individual level, hearing loss has been shown to be associated with financial hardship (Emmett & Francis, 2015). Multiple studies have revealed that adults with severe-to-profound hearing losses are more likely to be unemployed or underemployed than the general population (Blanchfield, Feldman, Dunbar, & Gardner, 2001; Bonser, 1998; Hyde, 1988; Winn, 2005). Winn (2005) revealed that this this was true of adults within the Australian Deaf community despite access to higher education, and legislation prohibiting discrimination against individuals with hearing loss.

Blanchfield et al. (2001) have shown that individuals with a severe-to-profound hearing loss have on average, a lower level of education than the normal hearing population. Poor educational outcomes are not limited with those with severe-to-profound losses as it been repeatedly shown that mild hearing losses can effect speech and language development and educational performance in school children (Bess, Dodd-Murphy, & Parker, 1998; Blair, 1985; Kennedy et al., 2006; Khairi Md Daud, Noor, Rahman, Sidek, & Mohamad, 2010; Moeller, 2000). Jarvelin, Maki-Torkko, Sorri, and Rantakallio (1997) revealed that poor educational performance in these formative years carry over into adult life, leading to a lower likelihood of continuing in to higher education, and more frequent unemployment.

A study by Emmett and Francis (2015) has shown hearing loss to be independently associated with economic hardship in the United States. This study evaluated the data collected through a cross-sectional survey designed to assess the health of the civilian United States population every two years. The researchers showed that individuals with hearing loss had higher odds of having low educational attainments, higher odds of having a low income, and higher odds of being unemployed or underemployed when compared to the normal hearing population.

1.8 Noise-Induced Hearing Loss

It is unknown precisely when people first became aware that excessive exposure to noise could cause damage to one's hearing. Gilbert (1921) postulated humans must have been aware of the danger by the time they were capable of working metal. By the time of the industrial revolution the effect of excessive noise was becoming a recognised disorder. Due to the change from an agricultural to an industrial environment, the typical pattern of sound exposure dramatically changed (Thurston, 2013). Price (1914) reported that the volume of noise emitted from some factories could be heard hundreds of meters away, and some cities required factories to be constructed a certain distance away from the city limits to reduce nuisance noise.

After the Second World War thousands of troops returned to their home countries with NIHL caused militarily. Although hearing conservation programmes did not exist during the war, emphasis was placed upon diagnosing and rehabilitating service men and women who returned from the conflict with NIHL (McIlwain, Gates, & Ciliax, 2008). This drive to rehabilitate eventually led to the field of audiology as it exists today (Katz et al., 2009).

Due to the increased ambient noise levels of the modern world (Chepesiuk, 2005) NIHL has become the second-most common form of acquired hearing loss worldwide (Mehrparvar et al., 2014). This has prompting the creation of governmental noise legislation (Grad & Hack, 1972) and education programmes designed to reduce its impact (Holger, 1980; Richardson, Thompson, Coghill, Chambers, & Turnock, 2009).

1.9 Causes of Noise-Induced Hearing Loss

Noise-induced hearing loss is caused by exposure to excessive levels of sound (Ivory, Kane, & Diaz, 2014; Lewis & Bear, 2008; Schlauch & Nelson, 2009). The damage associated with NIHL occurs cumulatively over a period of time due to repeated or prolonged exposure to loud sound (Boger, Barbosa-Branco, & Ottoni, 2009). Noise-induced hearing loss is considered to be one of the most-common occupational diseases worldwide (Chepesiuk, 2005). However, as it may also occur due to recreational pursuits, it is not considered solely an occupational occurrence (Amirabadi, 2012; Ivory et al., 2014).

Noise-induced hearing loss caused during recreational activities such as attending concerts, motorcycling, hunting and using personal music devices is usually termed recreational noise-induced hearing loss (RNIHL) (Ivory et al., 2014; Williams, Beach, & Gilliver, 2010). NIHL that occurs within a in a work environment is defined as occupational noise-induced hearing loss (ONIHL) (Azizi, 2010a). These two categories of NIHL are not mutually exclusive, and an individual with NIHL may have both occupational and recreational components to their hearing loss (Neitzel, Seixas, Goldman, & Daniell, 2004; Williams et al., 2010).

The severity of a NIHL is primarily dependent on the duration of exposure and the intensity of sound (Azizi, 2010a). Noise-induced hearing loss usually presents as a symmetrical (Chung, Mason, Willson, & Gannon, 1983; Haboosheh & Brown, 2012), high-frequency hearing loss (Dib, Silva, Morais, & Trevisani, 2008b). In cases of NIHL the 3000 Hz to 6000 Hz frequency range is typically the first area of an individual’s hearing thresholds to deteriorate (Sataloff & Sataloff, 1998; R. Wilson, 2011). An audiometric notch centred at 4000 Hz is often present in cases of NIHL, and has traditionally been considered a tell-tale sign of noise exposure (McBride & Williams, 2001). However, this notch has also been found in individuals with no history of noise exposure and can also be caused by non-noise related conditions (McBride & Williams, 2001).

1.9.1 Pathophysiology of Noise-Induced Hearing Loss

A sensorineural hearing loss NIHL affects the auditory system at the inner ear (Anthwal & Thompson, 2015). When excessive sound waves reach the inner ear, they can cause damage in several ways.

1.9.2 Hair cell damage/death

Excessive sound has the potential to cause damage to stereocilla hair cells within the cochlea (Rabinowitz, 2000). When overstimulated, these cells produce reactive oxygen species (ROS) which are toxic to the hair cells and can cause cell damage due to metabolic exhaustion (Harrison, 2012), and oxidative cell death (Henderson, Bielefeld, Harris, & Hu, 2006).

When a hair cell dies, supporting cells located beneath the cell expand to replace the damaged cell and seal the barrier between the perilymph of the Scala Tympani and the endolymph of the Scala Media. This ensures the conservation of the remaining hearing as the mixture of these two fluids causes a depolarisation of the primary afferent neurons leading to complete hearing loss (Raphael, 2002).

Damage from noise primarily effects the outer hair cells (OHC) which are more sensitive to sound than inner hair cells (IHC) (Chen & Fechter, 2003). The role of the OHCs is to amplify the movement of the basilar membrane and sharpen the tuning of the auditory system to improve frequency resolution (Oghalai, 2004). The loss of OHCs can cause distortion and attenuation of the audio signal (Smith, Moody, Stebbins, & Norat, 1987).

Although IHCs are more resilient to noise insult, their death can lead to dead regions upon the cochlea’s tonotopic map (Engstrom, 1983; Moore, 2001). As transduction is unable to occur in these regions, the characteristic frequencies of the dead IHCs will no longer be perceived (Moore, Huss, Vickers, Glasberg, & Alcantara, 2000). Hair cell death resulting in a permanent sensorineural hearing loss is known as a permanent threshold shift (PTS) (Alberti, 1992).

1.9.3 Nerve damage

Over exposure to sound can also cause a reduction in the amount of myelin along the auditory nerve (Tagoe, Barker, Jones, Allcock, & Hamann, 2014). Myelin consists of many different types of cells and has the appearance of a white fatty substance (Boullerne, 2016). It provides electrical insulation to neural fibres improving the transmission speed of impulses propagating along the nerve (Hartline, 2008). A lack of myelin slows down the transmission velocities of impulses to the auditory cortex (Brown & Hamann, 2014; Wan & Corfas, 2017) reducing the intelligibility of sound by delaying the auditory perception. This deficit becomes particularly apparent in noisy environments (Brown & Hamann, 2014).

1.10 Temporary Threshold shift

In addition to permanent hearing loss, excessive sound exposure can lead to a temporary threshold shift (TTS) (Kujawa & Liberman, 2009; Plontke & Zenner, 2004). A TTS Is a transient form of sensorineural hearing loss that generally lasts for between 24 and 48 hours (Humes, Joellenbeck, & Durch, 2005). A TTS can occur due to uncoupling of stereocilia from the tectorial membrane, metabolic stress (Plontke & Zenner, 2004) or synaptic damage caused by an excessive release of neurotransmitter (Puel, Ruel, d'Aldin, & Pujol, 1998). Unlike a PTS, after a TTS hearing thresholds recover after the cessation of noise (Koh & Takahashi, 1996). However, there can be no guarantee that the reduction in hearing is entirely due to a TTS and that hearing will return to pre-exposure levels (Chan, Ho, & Ryan, 2016; Harada, Ichikawa, & Imamura, 2008).

1.11 Susceptibility to Noise-Induced Hearing Loss

Studies have shown that susceptibility to NIHL varies from person-to-person (Sliwiniska-Kowalska, Pawelczyk, & Kowalski, 2006). This means two individuals exposed to the same level of sound for the same duration will not necessarily develop the same degree of hearing loss (OiSaeng Hong et al., 2013). It is thought that susceptibility to NIHL is dependent on an interaction of intrinsic and environmental factors (Śliwińska-Kowalska et al., 2006). Studies have shown that an abnormal acoustic reflex (Colletti & Sittoni, 1986), blood pressure, eye colour, gender, age and genetic makeup are intrinsic factors that may affect NIHL susceptibility (Śliwińska-Kowalska et al., 2006). Examples of environmental factors include: smoking (Prince & Matanoski, 1991), exposure to certain chemicals, recovery time between subsequent exposures, and the use of ototoxic medication (Arve Lie et al., 2016).

1.12 Acute Acoustic Trauma

Acute acoustic trauma (AAT) refers to an injury caused by a sudden intense sound (Haboosheh & Brown, 2012). It is often caused by explosions or gun shots and is common amongst military personnel (Medina-Garin et al., 2016; Yehudai, Fink, Shpriz, & Marom, 2017). A sound pressure level of approximately 140 dB SPL is required for acoustic trauma to occur (Stewart, Pankiw, Lehman, & Simpson, 2002; R. Wilson, 2011).

Acute acoustic trauma usually results in a TTS that will recover over time, but in severe cases the loss may be permanent in nature (Haboosheh & Brown, 2012). Acute acoustic trauma can result in a conductive hearing loss through a rupture of the TM or the dislocation of the ossicular chain. It can also cause sensorineural hearing loss through damage to the inner ear (P. Alberti, 1998). Unlike NIHL, AAT often causes an asymmetrical hearing loss as the ear facing towards the event bears the brunt of the damage (Stewart et al., 2002).

1.13 Occupational Hearing Loss

Occupational hearing loss (OHL) is an umbrella term for any type of hearing loss that occurs in an occupational environment (The National Institute for Occupational Safety and Health, 2017). This is opposed to recreational hearing loss (RHL) which occurs due to recreational pursuits (Deloitte Access Economics, 2006). Occupational hearing loss is a preventable form of hearing loss (Akhil & Vishwambhar, 2014; Alexopoulos & Tsouvaltzidou, 2015; Le, Straatman, Lea, & Westerberg, 2017; Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005).

NIHL is the most common cause of OHL. The vast majority of NIHL cases are due to noise exposure in an occupational setting (Akhil & Vishwambhar, 2014). The World Health Organisation (2002) reported that on a global level, an estimated one-sixth of all hearing loses are caused by workplace noise exposure. Nelson, Nelson, Concha-Barrientos, and Fingerhut (2005) found that approximately 7% of the working population in developed countries and 21% in developing regions have a disabling ONIHL. Occupational noise-induced hearing loss accounted for approximately one-third of all occupational disease notifications in New Zealand from 1992 to 2000 (Thorne et al., 2008). This was surpassed in frequency only by occupational overwork syndrome. Between July 1995 and June 2006, the number of annual claims lodged with the New Zealand Accident Compensation Commission (ACC) for Occupational NIHL increased by 97%. This resulted in a total cost to ACC of $193.82 million over this period (Thorne et al., 2008).

In addition to gradual NIHL, AAT is another common cause of OHL. Occupational AAT is common amongst active military personnel who are regularly exposed to impulse noise (Celli, Ribas, & Zannin, 2008; Melnick, 1991; Nordmann, Bohne, & Harding, 2000; Rabinowitz, 2000). Medina-Garin et al. (2016) revealed that in the French military 10,043 cases of AAT were reported to the French Armed Forces Centre for Epidemiology and Public Health (CESPA) between 2007 and 2014. The total prevalence of AAT is however difficult to determine as many individuals do not seek immediate medical attention after an AAT injury (A Axelsson & Hamernik, 1987). This causes continuous noise exposure to become a confounding factor in identifying the presence and severity of an AAT injury, as it is difficult to isolate damage caused by AAT from damage resultant from long-term noise exposure (Axelsson & Hamernik, 1987).

Hawkins (as cited in Bisht & Bist, 2011 p.255) describes ototoxicity as “the tendency of certain therapeutic agents and other chemical substances to cause functional impairment and cellular degeneration of the tissues of the inner ear, and especially of the end-organs and neurons of the cochlear and vestibular divisions of the eighth cranial nerve”. Ototoxicity may affect the cochlea leading to sensorineural hearing loss and/or tinnitus (Bisht & Bist, 2011). Alternatively, ototoxic chemical exposure may damage the semi-circular canals leading to dysfunction of the vestibular system (Zingler et al., 2009).

Many chemicals of varying ototoxicity are used in industry (Parent-Thirion, Fernández Macías, Hurley, & Vermeylen, 2007). In addition to overtly ototoxic chemicals, other chemicals such as carbon monoxide are known to interact synergistically with NIHL, whilst not in themselves being ototoxic (Nies, 2012). Many chemicals have not been evaluated to determine whether they constitute a risk to the inner ear (Glaser, 1997). Studies have suggested that interactions between noise exposure and chemical exposure often cause the degree of an OHL to be greater than as can be expected by each individual factor (Guida, Morini, & Cardoso, 2010; Mirzaei & Ansari-Moghaddam, 2013; Morata, 1989; Steyger, 2009).

Hannah, Page, and McLaren (2016) found that in New Zealand workers in the mining, construction and manufacturing industries are at the greatest risk of OHL. These results are echoed in the United States where a study by Masterson (2016) used the results of audiograms collected by The National Institute of Occupational Safety and Health (NIOSH) to show that the fields with the highest risk of OHL were mining with 17% of workers effected, followed by construction (16%) and manufacturing (14%).

1.14 Hearing Conservation

Hearing conservation programmes (HCP) are designed to protect workers from OHL (Pyykkö, Toppila, Starck, Juhola, & Auramo, 2000). They are often mandated by governmental legislation (Arenas & Suter, 2014) and consist of a series of different components that work in tandem to ensure the best protection of workers realistically possible under the circumstances (Pyykkö et al., 2000).

In New Zealand, hearing regulation is overseen by WorkSafe New Zealand. WorkSafe ensure that regulations are being correctly implemented by the employer on behalf of the New Zealand government. WorkSafe New Zealand operates under the Health and Safety Work Act of 2015 (WorkSafe New Zealand, 2017).

Similar oversight can be found internationally (International Labour Organisation, n.d.; Pyykkö et al., 2000). However, in some cases hearing conservation for individual industries is controlled by administrative bodies specific to the field rather than a single, overarching administrative body (Beamer, 2008; Center for Disease Control and Prevention, 1998; Schulz, 2007).

1.15 Noise Legislation

In New Zealand, the Health and Safety in Employment act of 1995 Regulation 11 requires that all employers take practical steps to ensure that no employee is exposed to noise in excess of an eight-hour, equivalent continuous A-weighted sound pressure level of 85 dB(A). In addition, the peak sound levels should never exceed 140 dB regardless of whether the employee is wearing hearing protection (New Zealand Government, 1995). Furthermore, the regulations state that hearing protection can only be used to reduce noise exposure to below the 85 dB(A)leq threshold when all other practical steps of controlling the noise have been exhausted.

This is a common approach to restricting noise exposure, and similar standards can be seen laid out in the Health and Safety at Work etc. Act in the United Kingdom (The Parliament of the United Kingdom, 1974) and the United States Occupational Safety and Health Standards (United States Department of Labor, 1970).

1.16 Components of a Hearing Conservation Initiative

Lipscomb (1988) postulated that HCPs could be said to consist of three basic components: qualify, abate, protect. This framework provides an insight into the structure of a simple HCP.

1.16.1 Qualify

The first component is the qualification of a work environment for the HCP. To qualify for hearing conservation the noise level of the environment must first be measured. The measured value is compared to the governmental legislation to determine whether the workplace exceeds the allowable level of noise. These measurements must serve as a representation of the level of sound exposure workers may be subjected to. There is no need to ensure a room is below the maximum allowable noise level if there are no employees working there. Measurements of the peak sound level and average sound level are collected from the work environment using sound level meters. If the regulation for the allowable peak level is exceeded, reduction of noise levels is immediately required. However, in the case of the average noise level in an environment the duration of the employee's exposure must be considered (Lipscomb, 1988).

This is achieved using a time/intensity trade off system. Rather than specifying an average level of noise that may not be exceeded, the maximum exposure is legislated in terms of an equivalent continuous exposure sound pressure level. This acts as a sliding scale where the average level of continuous sound may be increased but the length of time a worker can remain within that environment must be reduced (Lipscomb, 1988).

If a workplace does not meet these requirements it is considered to have qualified for the HCP and additional controls must be implemented to reduce exposure to damaging noise (Lipscomb, 1988).

1.16.2 Abate

Abatement is the most effective method of reducing occupation noise (The National Institute for Occupational Safety and Health, 2015). Abatement aims to prevent excessive noise from reaching the worker in the first place (Organisation for Economic Co-operation and Development, 2008). Engineering controls such as: redesigns of noisy equipment, maintenance to reduce operating noise, or isolating noisy equipment from the worker's station using sound baffles or enclosures can be used to achieve this goal (Lipscomb, 1988; Suter, 2012). Engineering controls are considered the most important approach to noise abatement because they constitute the most reliable method of reducing exposure (Suter, 2012).

In the absence of practical engineering solutions, administrative controls can be used to limit an employee's exposure time. This may take the form of adjusting workers schedules to limit their time at noisy work stations, or rotating them into different environments to ensure their exposure limit is not exceeded. (Lipscomb, 1988; Suter, 2012).

Although noise abatement is generally mandated as the first step taken to reduce noise exposure it is sometimes unfeasible to reduce noise to within safe levels by these means alone (Occupational Safety and Health Service, 1996). This may be due to a lack of the technological ability, or prohibitive costs (Lipscomb, 1988).

1.16.3 Protect

If abatement procedures cannot eliminate the risk of OHL entirely, hearing protective devices (HPDs) should be employed (Lipscomb, 1988; Occupational Safety and Health Service, 1996; Suter, 2012).

In New Zealand HPDs are assigned a rating dependent on how much noise isolation they provide (Ministry of Business, 2013). A class 1 hearing protection is only effective up to 90 dB of equivalent continuous sound, while class 5 is sufficient for up to 110 dB. It is therefore vital that the HPD is fit for purpose (Ministry of Business, 2013). Extra attenuation can be achieved by pairing a set of ear plugs with a set of ear muffs thus providing two levels of isolation (Berger, 1983).

HPDs can be of passive or active design. Where passive ear muffs attenuate sound solely based upon the material they are constructed out of, active ear muffs use electronic circuitry to induce phase cancellation and reduce sound levels (Brown et al., 2015). Active HPDs are particularly effective for reducing low frequency noise (Zimpfer & Sarafian, 2014).

There are several barriers to the effectiveness of hearing protection. The foremost being its fit. Ill-fitting ear muffs or ear plugs can allow sound to leak through the HPD compromising the user's protection (Voix & Hager, 2009). In the case of ear muffs, even concurrent wear of eye glasses can reduce the attenuation by up 3-7 dB by obstructing the HPD's seal (Berger, 1988).

The condition of the HPD should be inspected regularly because as with any item, heavy use can cause the deterioration of its construction (Royster & Royster, 1990). As with ill-fit this can compromise the seal and allow sound to pass through (Royster & Royster, 1990).

HPDs also provide challenges to communication in the workplace. This can be particularly problematic in dangerous jobs where clear communication is vital, or in cases where the employee already has a hearing loss (Yankaskas, 2016). In these situations ear muffs with built-in communication systems may be appropriate (Ministry of Business, 2013).

Comfort and ease of use have been shown as important considerations in the choice of HPD. Hsu, Huang, Yo, Chen, and Lien (2004) revealed that because of uncomfortable and difficult to use HPDs many workers do not use their hearing protection consistently or correctly.

1.17 Audiometric Monitoring

Monitoring of both the hearing thresholds of employees via audiometry, and environmental sound levels through re-assessment is an important part of any HCP (Lipscomb, 1988). Annual hearing checks provide a method of evaluating the programme's effectiveness. Re-assessment ensures that the noise level in the work environment has remained constant and does not require further attention (Lipscomb, 1988).

1.18 Educational Initiatives

HPD use is only effective if it is used correctly. Murphy et al. (2004) revealed that employees who are not taught the correct way of inserting ear plugs gain little benefit from wearing them. Other factors that may influence an individual's decision not to use HPDs include: a fatalist attitude towards the possibility of future hearing loss (Kelly, Boyd, & Henehan, 2015; Reddy, Welch, Thorne, & Ameratunga, 2012), peer pressure, difficulty interacting with co-workers while wearing HPDs, and a lack of understand regarding NIHL (Reddy et al., 2012). This necessitates that employees are given training on how to use any HPDs that they are provided with, and ensuring that employees have the base knowledge and motivation required to follow the HCP (Groenewold, Masterson, Themann, & Davis, 2014). It is suggested that initial training and annual refresher courses are appropriate steps to ensure that workers have the required base knowledge (Rawool, 2012).

Motivational techniques such as: encouraging employees to take an interest in the results of audiometric monitoring, giving praise for correct use of their HPDs, and checking that the employees finds their HPDs comfortable have been suggested as methods of improving HPD use (Berger, 1987)

1.19 Research Rationale

The evaluation of interventions is an important part of ensuring that the best possible outcomes are being achieved. The results of evaluation have the ability to improve preventive practice (Doll, Bartenfeld, & Binder, 2003). This has been shown repeatedly in different fields of research. For example, after the impact of helmets upon traumatic head injuries was demonstrated, the use of bicycle helmets increased (Rivara et al., 1994; Thompson, Rivara, & Thompson, 1996; Thompson, Rivara, & Thompson, 1989). Drink driving laws reducing the blood alcohol limit to 0.08% were more widely adopted after studies had shown a correlation between these laws and a decrease in fatal car accidents (Freeman, 2007; Shults et al., 2001; Shults et al., 2002). The number of smoke detector installation initiatives and fire safety education programmes increased after they were shown to be a highly effective (Haddix, Mallonee, Waxweiler, & Douglas, 2001; Mallonee et al., 1996).

Although OHL is a preventable condition, studies evaluating the efficacy of OHL prevention and surveillance initiatives are rarely published (Alexopoulos & Tsouvaltzidou, 2015). In order to address this lack of evaluation the present study was designed to provide a roadmap for future researchers by exploring the range of literature available about OHL interventions, and the outcome measures that can be used to assess their effects. This outcome was achieved by performing two scoping reviews.

This study primarily focused upon OHL caused by noise (NIHL and AAT). Ototoxicity and other OHL causes were also considered, if they were being discussed in relation to their interaction with noise exposure.

1.20 Scoping Reviews

Mays, Roberts, and Popay (2001) wrote that a scoping review aims to rapidly map the key concepts underpinning a research area allowing the researcher to determine the types of evidence that is available, and where that literature can be found.

There are many different uses for a scoping review. Arksey and O'Malley (2005, p. 21) describe four common uses. (1) A scoping review can be used "to examine the extent, range and nature of research activity." (2) A scoping review may be used to determine whether a systematic review is necessary. (3) A scoping review can be used to aid in summarising and disseminating information to medical professionals or consumers. (4) A scoping review may be used to identify gaps in the current understanding of a research area, providing a summary of the state of the on-going research activity.

Scoping reviews differ from comprehensive systematic reviews in several ways. A systematic review considers a narrowly-defined research question, while a scoping review is designed to have a far wider scope allowing broadly-defined questions to be answered (Higgins & Green, 2011). Where a comprehensive systematic review considers the quality of the literature, a scoping review does not (Arksey & O'Malley, 2005). This allows a scoping review to incorporating a wider range of evidence than a systematic review (Dijkers, 2015).

Most authors who have written about the scoping review format have said that there are no well-established criteria related to how a scoping review should be performed (Dijkers, 2015). However, the majority derive their methodology either directly or indirectly from Arksey and O'Malley (2005). This makes the scoping review a versatile study design as it can be easily adapted to the needs of the project at hand (Dijkers, 2015).

1.21 Research Questions

The research question that was addressed by the first scoping review was:

"What types of prevention strategies for OHL have been reported in the literature?"

The first scoping review analysed the variety of intervention strategies discussed in the literature and summarised the findings.

The research question that was addressed by the second scoping review was:

"What types of outcomes relating to the prevention of OHL have been reported in the literature?"

The second scoping review analysed the variety of outcome measures used to evaluate OHL interventions that have been discussed in the literature and summarised the findings.

2.0 Methods

2.1 Eligibility criteria

In a scoping review the research question is framed by defining three elements: population, concept, context (PCC) (Joanna Briggs Institute, 2014). This differs from the PICO (population, intervention, comparison, outcome) format recommended for comprehensive systematic reviews by the Cochrane Collaboration (Higgins & Green, 2011) owing to the desire for a broader focus when scoping (Arksey & O'Malley, 2005). For each review discussed here sources were required to meet a set of criteria based upon the PCC elements in order to be considered for review.

Eligibility criteria for scoping of OHL interventions:

1. **Population:** The participants investigated in the source were required to be adults (as defined by their locality) with OHL. They were not required to be a specific sex, age, ethnicity, or socioeconomic status.
2. **Concept:** The concept discussed in the source was required to be intervention strategies to prevent OHL in adults exposed to hazardous levels of sound in the workplace. This included studies where noise was discussed in tandem with other risk factors for OHL.
3. **Context:** All sources involving adults with OHL were eligible for inclusion irrespective of locality.

Eligibility criteria for scoping of OHL outcome measures:

1. **Population:** The participants investigated in the source were required to be adults (as defined by their locality) with OHL. They were not required to be a specific sex, age, ethnicity, or socioeconomic status.

2. **Concept:** The concept discussed in the source was required to be the outcomes of intervention strategies to prevent OHL in adults exposed to hazardous levels of sound in the workplace. This included studies where noise was discussed in tandem with other risk factors for OHL.
3. **Context:** All sources involving adults with OHL were eligible for inclusion irrespective of locality.

Compared to a comprehensive systematic review design, scoping reviews are far more flexible with the variety of sources that may be included (Peterson, Pearce, Ferguson, & Langford, 2016). These can include: primary research studies, reviews, guidelines, and opinion papers (Joanna Briggs Institute, 2014). The decision of which types of sources will be included in a specific review can be expanded or constrained depending on what the reviewer deems to be appropriate (Armstrong, Hall, Doyle, & Waters, 2011). In the reviews discussed via this research, sources were required to be available in English and published in a refereed publication. This was to prevent marketing material to be selected for the review. Grey literature such as theses and governmental reports were eligible to be included in the review.

2.2 Information Sources

The searches for both scoping reviews were conducted on the 8th of May 2017. These searches were conducted using the University of Canterbury's library Multisearch engine. Multisearch is an academic search engine based upon ProQuest's Summon 2.0 platform. Multisearch enables the University of Canterbury's entire collection of databases to be searched at the same time (ProQuest, n.d.-b). Multisearch includes the indexing of: Cumulative Index to Nursing and Allied Health Literature (CINHL), The Cochrane Library, MEDLINE, PubMed, and

Web of Science along with many other research databases. This wide variety of databases ensured a broad range of results.

2.3 Search Strategy

The initial searches were performed using keywords derived from the research questions. Filters were used to restrict the results to those written in English, and to remove types of sources that did not fit the eligibility criteria. Results were sorted by relevance via Multisearch. This means that results were listed in order of the most closely-related to the search terms (ProQuest, n.d.-a). Although Multisearch identified 1,727 sources relating to the OHL interventions and 1,684 relating to OHL outcome measures it is limited to returning a maximum of 200 results. However, because results are organised in terms of their relevance, no new information was discovered near the end of the lists and screening of results for eligibility was concluded when this number was reached. The search strategies for the OHL intervention scoping review (table 1) and the outcome measures scoping review (table 2) are presented below.

Table 1. Search strategy for OHL interventions scoping review.

Search engine	*Search terms*
University of Canterbury Multisearch (ProQuest Summon 2.0)	((adults) AND ("hearing loss") AND (occupational) AND (noise) AND (prevention))

Table 2. Search strategy for OHL outcome measures scoping review.

Search engine	*Search terms*
University of Canterbury Multisearch (ProQuest Summon 2.0)	((adults) AND ("hearing loss") AND (occupational) AND (noise) AND (outcome))

2.4 Study selection

The author read the abstracts from the initial searches to determine whether the sources were relevant to the review question. Each source was then divided into categories of ‘include’ and ‘exclude’ based upon the eligibility criteria. Each article then underwent thematic evaluation using its abstract or if necessary, the full text version to determine what intervention or outcome measure was being studied. The sources in the include category were then further divided into groups depending on the specific intervention or outcome measure that was being discussed. Main themes related to each study were identified, and these themes were then grouped to identify the most common findings related to each intervention. Some studies qualified for eligibility under multiple categories and were therefore added to multiple groups. Articles in the exclude category were further divided into groups based upon the reason they were excluded.

2.5 Software

Articles were organised into groups using Clarivate Analytics Endnote X8 citation manager. Flowcharts showing the progression of the search were developed using Microsoft Excel and eDrawSoft’s eDraw Max free edition. Both Microsoft Excel and Endnote X8 were under licence to the University of Canterbury.

3.0 Results of the Intervention Scoping Review

3.1 Included Studies

The results of the systematic search uncovered literature discussing: audiometric monitoring, administrative controls, engineering controls, hearing conservation programmes (HCP), hearing protection devices (HPD), legislation/regulation, pharmacological otoprotection and training/educational initiatives. In total, 90 sources meeting the eligibility criteria were discovered. Many sources were found to discuss multiple intervention strategies. These studies have therefore been included under multiple subheadings in this chapter. A flowchart displaying the inclusion and exclusion pathways of this review can be seen below in figure 1.

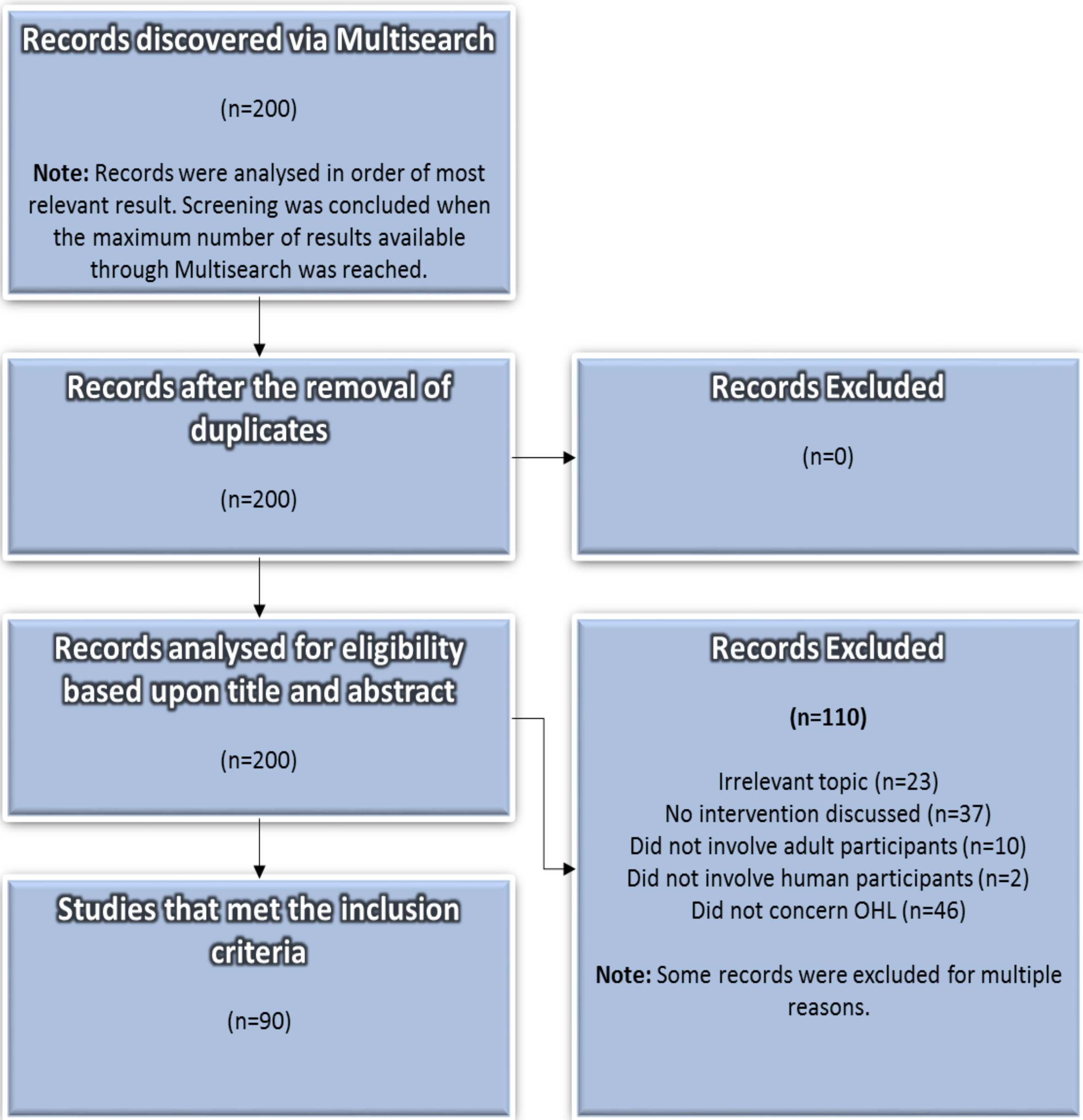

Figure 1: Inclusion and exclusion pathways of the intervention scoping review.

3.2 Audiometric Monitoring

Fourteen studies discussing audiometric monitoring of employees met the inclusion criteria for the intervention scoping review (Daniell et al., 2002; Dube, Ingale, & Ingale, 2011; Hong, 2005; Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007; Job et al., 2009; Karimi, Nasiri, Kazerooni, & Oliaei, 2010; McCullagh, Raymond, Kerr, & Lusk, 2011a; Mehrparvar, Mirmohammadi, Ghoreyshi, Mollasadeghi, & Loukzadeh, 2011; Mohammadi, Mazhari, Mehrparvar, & Attarchi, 2010; Ologe, Akande, & Olajide, 2006; Ologe, Olajide, Nwawolo, & Oyejola, 2008; Pelegrin, Canuet, Rodriguez, & Morales, 2015; Prince, Colligan, Stephenson, & Bischoff, 2004; Soalheiro et al., 2012).

The most common themes reported in the literature show that a baseline hearing test and regular audiometric assessment is necessary to improve hearing outcomes for noise exposed employees (Dube et al., 2011; Hong, 2005; Karimi et al., 2010; Ologe et al., 2006; Ologe et al., 2008; Pelegrin et al., 2015; Soalheiro et al., 2012), but that audiometric monitoring is not always conducted in noisy industries (Daniell et al., 2002; Hong, 2005; Ologe et al., 2006). Employees who were monitored often had little idea of what the results of their hearing tests showed, and were unable to identify changes in their hearing subjectively (Daniell et al., 2002; McCullagh et al., 2011a; Pelegrin et al., 2015).

Table 3: Studies discussing audiometric monitoring.

Theme	Reference	Journal	Study Location
A baseline hearing test and regular audiometric examination is required to improve outcomes for noise exposed employees.	(Dube, Ingale, & Ingale, 2011)	Noise & Health	India
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(Ologe, Akande, & Olajide, 2006)	European Archives of Oto-Rhino-Laryngology	Nigeria
	(Ologe, Olajide, Nwawolo, & Oyejola, 2008)	The Journal of Laryngology and Otology	Nigeria
	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain
	(Soalheiro et al., 2012)	Journal of Occupational Medicine and Toxicology	Brazil
	(Karimi, Nasiri, Kazerooni, & Oliaei, 2010)	Noise & Health	Iran
Not all companies provide regular annual audiometric testing.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(Ologe, Akande, & Olajide, 2006)	European Archives of Oto-Rhino-Laryngology	Nigeria
Employees often do not understand their audiometric results, and self-reported changes in hearing are a poor indicator of audiometric thresholds.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA
	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain
	(McCullagh, Raymond, Kerr, & Lusk, 2011)	Noise & Health	USA

Regular testing is not always present in industries where employees are exposed to intermittent noise. (e.g., construction)	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(Soalheiro et al., 2012)	Journal of Occupational Medicine and Toxicology	Brazil
DPOAEs can be used in HCPs to measure vulnerability to noise and early NIHL.	(Job et al., 2009)	Hearing Research	France
	(Ologe, Akande, & Olajide, 2006)	European Archives of Oto-Rhino-Laryngology	Nigeria
Companies often organise testing through an independent contractor.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA
It may not be practical for employees with part time or short-term contracts to be regularly tested.	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
Self-administered audiometric screening can be successfully used as part of a HCP.	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
An intervention based on screening and education can increase HPD use.	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
Screenings at public events are an effective method of reaching populations at risk of OHL.	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
High frequency audiometry is more sensitive than conventional audiometry for early detection of NIHL.	(Mehrparvar, Mirmohammadi, Ghoreyshi, Mollasadeghi, & Loukzadeh, 2011)	Noise & Health	Iran
Audiometric monitoring may be restricted by lack of facilities.	(Ologe, Akande, & Olajide, 2006)	European Archives of Oto-Rhino-Laryngology	Nigeria

Exclusive reliance on audiometric testing (or noise surveillance) cannot fully show the effectiveness of a HCP.	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA

Note. *DPOAE = distortion product otoacoustic emissions, HCP = hearing conservation programme, HPD = hearing protection devices, NIHL = noise-induced hearing loss, USA = United States of America*

3.3 Administrative controls

Six sources discussing administrative control strategies met the inclusion criteria for the intervention scoping review (Chou, Lai, & Kuo, 2009; Daniell et al., 2002; Karimi et al., 2010; McTague et al., 2013; Pelegrin et al., 2015; Prince et al., 2004).

The most commonly-reported themes in the literature showed that employees in noisy work environments may not have enough information to appreciate the importance of environmental noise monitoring and other methods of administrative noise control (Daniell et al., 2002; Prince et al., 2004). Measurements of ambient noise levels and noisy workstations are not always recorded regularly to monitor changes (Daniell et al., 2002; Prince et al., 2004).

Table 4: Sources discussing administrative control strategies

Theme	Reference	Journal	Study Location
Employees may have little knowledge about acceptable noise levels and environmental monitoring.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA
	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA
Measurements of ambient noise are not always regularly recorded.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA
	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA
Scheduling shifts to allow workers' auditory systems to recover can reduce overall NIHL.	(Chou, Lai, & Kuo, 2009)	Noise & Health	Taiwan
Reducing the number of hours per day employees are in noisy environments can reduce NIHL in occupations where engineering control is not possible.	(Karimi, Nasiri, Kazerooni, & Oliaei, 2010)	Noise & Health	Iran
Workers will voluntarily monitor their noise dosage if equipment is provided.	(McTague et al., 2013)	International Journal of Audiology	USA
Exposure monitoring can enable a reduction in daily noise exposure.	(McTague et al., 2013)	International Journal of Audiology	USA
Providing feedback on their daily noise dosage allows workers to take steps to avoid excess exposure (HPD use/avoiding noisy areas).	(McTague et al., 2013)	International Journal of Audiology	USA
Exposure monitoring allows excessive noise to be brought to the attention of management.	(McTague et al., 2013)	International Journal of Audiology	USA
Routine monitoring of noise should be included in a HCP.	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain

The use of monitoring systems can aid the identification of tasks with dangerous levels of noise and are not currently considered high risk.	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain
While engineering controls are first in the hierarchy of controls, HPDs should be employed until monitoring confirms that there is no risk of OHL.	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA
Use of engineering controls cause less emphasis to be placed upon administrative control strategies.	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA
Not all companies keep records of their noise measurements.	(Daniell et al., 2002)	American Journal of Industrial Medicine	USA

Note: NIHL = noise-induced hearing loss, HPD = hearing protection device, HCP = hearing conservation programme, OHL = occupational hearing loss, USA = United States of America

3.4 Engineering Controls

Eleven studies discussing engineering control strategies met the inclusion criteria of the intervention scoping review (Daniell et al., 2006; Gates & Jones, 2007; Hong, 2005; Hong, Chin, Phelps, & Joo, 2016; Hwang et al., 2001; Karimi et al., 2010; Mihailovic et al., 2011; Nelson, Nelson, Concha-Barrientos, et al., 2005; Sliwinska-Kowalska & Davis, 2012; Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014; Voaklander, Franklin, Challinor, Depczynski, & Fragar, 2009).

The most common themes reported in the literature showed that engineering controls should be the first method utilised when aiming to decrease workers' noise exposure (Gates & Jones, 2007; Hwang et al., 2001; Mihailovic et al., 2011), and therefore should always be a component of HCPs (Daniell et al., 2006; Hong et al., 2016; Mihailovic et al., 2011). However, engineering controls are often prohibitively expensive (Gates & Jones, 2007; Hong, 2005) and often difficult to implement (Hong, 2005; Sliwinska-Kowalska & Davis, 2012).

Table 5: Sources involving engineering control strategies.

Theme	Reference	Journal	Study Location
Engineering controls should be the priority in reducing noise exposure.	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Mihailovic et al., 2011)	Environmental Monitoring and Assessment	Serbia
	(Hwang et al., 2001)	American Journal of Industrial Medicine	USA
Comprehensive HCPs should include engineering control strategies.	(Hong, Chin, Phelps, & Joo, 2016)	Workplace Health & Safety	USA
	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Mihailovic et al., 2011)	Environmental Monitoring and Assessment	Serbia
Engineering controls are difficult to implement in certain industries.	(Sliwinska-Kowalska & Davis, 2012)	Noise and Health	Poland
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
Engineering solutions are often too expensive to implement.	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
Engineering controls are often overlooked as a method of reducing noise exposure.	(Voaklander, Franklin, Challinor, Depczynski, & Fragar, 2009)	Journal of Agricultural Safety and Health	Australia
	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
Engineering controls can be used to reduce occupational noise exposure.	(Nelson, Nelson, Concha - Barrientos, & Fingerhut, 2005)	American Journal of Industrial Medicine	USA
	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland
There is a lack of research evaluating engineering controls.	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland

Small and medium-sized companies are less likely to employ engineering controls.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
Engineering solutions should prioritise reduction of high-frequency sound.	(Mihailovic et al., 2011)	Environmental Monitoring and Assessment	Serbia
Audiometric monitoring results can be used to improve engineering controls.	(Voaklander, Franklin, Challinor, Depczynski, & Fragar, 2009)	Journal of Agricultural Safety and Health	Australia

Note: USA = United States of America

3.5 Hearing Conservation Programmes

Twenty-eight studies discussing HCPs met the inclusion criteria for the intervention scoping review (Ahmed, Dennis, & Ballal, 2004; Aliabadi, Farhadian, & Darvishi, 2015; Arezes & Miguel, 2005; Azizi, 2010b; Daniell et al., 2006; Davies, Marion, & Teschke, 2008; Helfer, Jordan, & Lee, 2005; Hong, 2005; Hong et al., 2016; Hong, Samo, Hulea, & Eakin, 2008; Lao et al., 2013; McCullagh, 2012; McCullagh et al., 2011a; Mihailovic et al., 2011; Mrena, Ylikoski, Mäkitie, Pirvola, & Ylikoski, 2007; Muhr & Rosenhall, 2011; Oestenstad, Norman, & Borton, 2008; Prince et al., 2004; Quick et al., 2008; Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007; Rubak, Kock, Koefoed-Nielsen, Bonde, & Kolstad, 2006; Saunders & Griest, 2009; Tak, Davis, & Calvert, 2009; Themann et al., 2015; Trost & Shaw, 2007; Verbeek et al., 2014; Voaklander et al., 2009; Wells et al., 2015).

The major themes showed that HCPs can successfully reduce incidences of OHL (Davies et al., 2008; O Hong, 2005; McCullagh, 2012; Mihailovic et al., 2011; Mrena et al., 2007; P Rabinowitz et al., 2007; Rubak et al., 2006). However, in many instances HCPs are either absent or missing vital components (Daniell et al., 2006; Hong, 2005; Hong et al., 2008; Lao et al., 2013; McCullagh et al., 2011a). Regular evaluations of HCPs are necessary to ensure that they are as effective as possible, and that the noise conditions of the environment have not changed (Helfer et al., 2005; Muhr & Rosenhall, 2011; Oestenstad et al., 2008; Trost & Shaw, 2007).

Table 6: Studies discussing hearing conservation programmes

Theme	Reference	Journal	Study Location
HCPs can successfully reduce the risk of OHL.	(Davies, Marion, & Teschke, 2008)	American Journal of Industrial Medicine	Canada
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(Mrena, Ylikoski, Mäkitie, Pirvola, & Ylikoski, 2007)	Acta Oto-Laryngologica	Finland
	(Rubak, Kock, Koefoed-Nielsen, Bonde, & Kolstad, 2006)	Noise & Health	Denmark
	(McCullagh, 2012)	Noise & Health	USA
	(Mihailovic et al., 2011)	Environmental Monitoring and Assessment	Serbia
	(Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007)	Occupational and Environmental Medicine	USA
Workplaces with excessive noise often have no HCPs in place, or their HCP is missing important components.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(McCullagh, Raymond, Kerr, & Lusk, 2011)	Noise & Health	USA
	(Lao et al., 2013)	PLoS ONE	Hong Kong
Regular evaluations of HCPs are necessary to ensure they are as effective as possible.	(Helfer, Jordan, & Lee, 2005)	American Journal of Audiology	USA
	(Muhr & Rosenhall, 2011)	Noise & Health	Sweden
	(Oestenstad, Norman, & Borton, 2008)	Military Medicine	USA
	(Trost & Shaw, 2007)	Military Medicine	USA

Workers may still be at risk of OHL even when covered by a HCP.	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland
	(Trost & Shaw, 2007)	Military Medicine	USA
For a HCP to be successful senior and middle managers should be involved in leadership roles.	(Helfer, Jordan, & Lee, 2005)	American Journal of Audiology	USA
	(Azizi, 2010)	The international journal of occupational and environmental medicine	Iran
HCPs do not remove the risk of hearing loss to workers who are exposed to a noise level under the threshold of implementation.	(Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007)	Occupational and Environmental Medicine	USA
	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland
Questionnaires addressing noise exposure and hearing loss may be useful alternatives to objective testing in the development of HCPs in developing countries where facilities for objective measurements are not available.	(Ahmed, Dennis, & Ballal, 2004)	International Journal of Hygiene and Environmental Health	Saudi Arabia
Advanced models for the prediction of NIHL can be utilised to modify and improve HCPs.	(Aliabadi, Farhadian, & Darvishi, 2015)	International Archives of Occupational and Environmental Health	Iran
Risk perception should be considered an essential issue in the design and implementation of HCPs.	(Arezes & Miguel, 2005)	Human Factors: The Journal of the Human Factors and Ergonomics Society	Portugal
HPD use is highest when a comprehensive HCP is in place.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA

HCPs should include tinnitus management interventions for noise-exposed workers.	(Hong, Chin, Phelps, & Joo, 2016)	Workplace Health & Safety	USA
HCP evaluation should include input from end-users in addition to audits of policy, procedure and hearing loss trends.	(Prince, Colligan, Stephenson, & Bischoff, 2004)	Journal of Safety Research	USA
Self-administered questionnaires may provide a low-cost way of assessing workers not currently under an HCP.	(McCullagh, 2012)	Noise & Health	USA
All HCPs should include occupational noise assessment, technical and organisational measures to control noise and prevent noise exposure, workers hearing evaluation and monitoring, and HPDs.	(Mihailovic et al., 2011)	Environmental Monitoring and Assessment	Serbia

Note: HCP = hearing conservation programme, OHL = occupational hearing loss, NIHL = noise-induced hearing loss, HPD = hearing protection device, USA = United States of America

3.6 **Hearing Protection Devices**

Forty-five sources that disscussed HPDs met the eligibility requirements of the intervention scoping review (Arezes & Miguel, 2005; Byrne, Davis, Shaw, Specht, & Holland, 2011; Choi et al., 2005; Chou et al., 2009; Clasing & Casali, 2014; Daniell et al., 2006; Dube et al., 2011; Edelson et al., 2009; Edward, Manohar, Somayaji, & Kallikkadan, 2016; Gates & Jones, 2007; Griffin, Neitzel, Daniell, & Seixas, 2009; Halevi-Katz, Yaakobi, & Putter-Katz, 2015; Hong, 2005; Hong, Chin, Fiola, & Kazanis, 2013; Hong et al., 2016; Hong, Fiola, & Feld, 2013; Hong et al., 2008; Hsu, Wu, Chang, Lee, & Hsu, 2013; Huttunen, Sivonen, & Pöykkö, 2011; Hwang et al., 2001; Jansen, Helleman, Schler, & Laat, 2009; Jenkins et al., 2007; Jirojwong, Joubert, & Anastasi, 2005; Marlenga et al., 2012; McTague et al., 2013; Moon, 2007; Morata et al., 2005; Mrena, Ylikoski, Kiukaanniemi, Mäkitie, & Savolainen, 2008; Neitzel et al., 2008; Norin, Emanuel, & Letowski, 2011; Ologe, Akande, & Olajide, 2005; Omokhodion, Adeosun, & Fajola, 2007; Patel et al., 2001; Pelegrin et al., 2015; Quick et al., 2008; Rabinowitz et al., 2007; Simpson, Bolia, McKinley, & Brungart, 2005; Solanki, Mehta, Shah, & Gokhale, 2012; Tak et al., 2009; Themann et al., 2015; Tufts, Hamilton, Ucci, & Rubas, 2011; Verbeek et al., 2014; Voaklander et al., 2009; Williams, 2011; Zander & Richter, 2008).

The most common themes identified in the literature showed that HPDs can be used to reduce incidences of OHL (Chou et al., 2009; Hong, 2005; Marlenga et al., 2012; Mrena et al., 2008; Pelegrin et al., 2015; Solanki et al., 2012; Themann et al., 2015; Verbeek et al., 2014), but not all employees who work in noise use HPDs (Daniell et al., 2006; Gates & Jones, 2007; Halevi-Katz et al., 2015; Hong, 2005; Hong, Chin, Fiola, et al., 2013; Hong, Fiola, et al., 2013; Hong et al., 2008; Jenkins et al., 2007; Marlenga et al., 2012; McTague et al., 2013; Ologe et al., 2005; Omokhodion et al., 2007; Rabinowitz et al., 2007; Solanki et al., 2012; Tak et al., 2009;

Zander & Richter, 2008). In addition HPDs are often used instead of, rather than in addition to, engineering and administrative control (Arezes & Miguel, 2005; Daniell et al., 2006; Marlenga et al., 2012).

Table 7: Studies discussing hearing protection devices

Theme	Reference	Journal	Study Location
Not all employees who are exposed to excessive noise use HPDs.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Halevi-Katz, Yaakobi, & Putter-Katz, 2015)	Noise & Health	Israel
	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Hong, Fiola, & Feld, 2013)	Workplace Health and Safety	USA
	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
	(Hong, Chin, Fiola, & Kazanis, 2013)	American Journal of Industrial Medicine	USA
	(Hong, 2005)	Berlin, Germany	USA
	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
	(McTague et al., 2013)	International Journal of Audiology	USA
	(Marlenga et al., 2012)	Occupational and Environmental Medicine	USA
	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
	(Solanki, Mehta, Shah, & Gokhale, 2012)	Indian Journal of Otology	India
	(Tak, Davis, & Calvert, 2009)	American Journal of Industrial Medicine	USA
	(Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007)	Occupational and Environmental Medicine	USA
	(Ologe, Akande, & Olajide, 2005)	Occupational Medicine	Nigeria
	(Zander, Spahn, & Richter, 2008)	Noise & Health	Germany
HPDs can successfully reduce the risk of OHL.	(Mrena, Ylikoski, Kiukaanniemi, Mäkitie, & Savolainen, 2008)	Acta Oto-Laryngologica	Finland
	(Chou, Lai, & Kuo, 2009)	Noise & Health	Taiwan

	(Hong, 2005)	International Archives of Occupational and Environmental Health	USA
	(Marlenga et al., 2012)	Occupational and Environmental Medicine	USA
	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain
	(Themann et al., 2015)	Occupational and environmental medicine	USA
	(Solanki, Mehta, Shah, & Gokhale, 2012)	Indian Journal of Otology	India
	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland
HPDs are often used instead of rather than in addition to engineering and administrative controls.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Arezes & Miguel, 2005)	Human Factors: The Journal of the Human Factors and Ergonomics Society	Portugal
	(Marlenga et al., 2012)	Occupational and Environmental Medicine	USA
HPD use is not related to perceived level of risk, or knowledge of hearing loss.	(Arezes & Miguel, 2005)	Human Factors: The Journal of the Human Factors and Ergonomics Society	Portugal
	(Ologe, Akande, & Olajide, 2005)	Occupational Medicine	Nigeria
	(Zander, Spahn, & Richter, 2008)	Noise & Health	Germany
HPDs have a negative impact on situational awareness and directionality.	(Simpson, Bolia, McKinley, & Brungart, 2005)	The Journal of the Human Factors and Ergonomics Society	USA
	(Morata et al., 2005)	Ear & Hearing	USA
	(Clasing & Casali, 2014)	International Journal of Audiology	USA

Individual beliefs and attitudes towards HPDs are strong predictor of HPD use.	(Edelson et al., 2009)	Annals of Occupational Hygiene	USA
	(Halevi-Katz, Yaakobi, & Putter-Katz, 2015)	Noise & Health	Israel
	(Quick et al., 2008)	Journal of Safety Research	USA
Employees may not use HPDs if they dislike how the environment sounds when HPDs are in use.	(Halevi-Katz, Yaakobi, & Putter-Katz, 2015)	Noise & Health	Israel
	(Huttunen, Sivonen, & Pöykkö, 2011)	Noise & Health	Finland
	(Jansen, Helleman, Schler, & Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
Ensuring HPDs fit the need of the workers and the job is a crucial step in preventing OHL.	(Hong, Fiola, & Feld, 2013)	Workplace Health and Safety	USA
	(Themann et al., 2015)	Occupational and environmental medicine	USA
	(Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007)	Occupational and Environmental Medicine	USA
Employees may not use HPDs because they interfere with communication.	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
	(Jansen, Helleman, Schler, & Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
	(Morata et al., 2005)	Ear & Hearing	USA
HPD use is low in developing countries.	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
	(Solanki, Mehta, Shah, & Gokhale, 2012)	Noise & Health	India
	(Ologe, Akande, & Olajide, 2005)	Occupational Medicine	Nigeria

Level-dependent HPDs can preserve the ability to hear speech whilst protecting from impulse noise.	(Norin, Emanuel, & Letowski, 2011)	Ear & Hearing	USA
	(Tufts, Hamilton, Ucci, & Rubas, 2011)	Noise & Health	USA
	(Williams, 2011)	Noise & Health	Australia
HPD use is highest where HCPs contain utilize all recommended components.	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Hong, Chin, Phelps, & Joo, 2016)	Workplace Health & Safety	USA
HPDs are not always available when they are required.	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Ologe, Akande, & Olajide, 2005)	Occupational Medicine	Nigeria
Employees may not use HPDs because they interfere with other safety considerations.	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
	(Morata et al., 2005)	Ear & Hearing	USA
Women are less likely than men to use HPDs.	(Jirojwong, Joubert, & Anastasi, 2005)	Southeast Asian Journal of Tropical Medicine and Public Health	Australia
	(Voaklander, Franklin, Challinor, Depczynski, & Fragar, 2009)	Journal of Agricultural Safety and Health	Australia
Barriers to HPD use can be divided into categories of environmental barriers and individual barriers.	(Patel et al., 2001)	Journal of Health Communication	USA
The use of HPDs as the first line of defense places the responsibility of protection on to the employee.	(Arezes & Miguel, 2005)	Human Factors: The Journal of the Human Factors and Ergonomics Society	Portugal

Use of HPDs can increase the risk of occupational injury.	(Choi et al., 2005)	American Journal of Industrial Medicine	USA
The comfort of HPDs is of greater importance to employees than the attenuation they provide.	(Byrne, Davis, Shaw, Specht, & Holland, 2011)	Noise & Health	USA
Employees usually either almost always use HPDs, or almost never use HPDs.	(Edelson et al., 2009)	Annals of Occupational Hygiene	USA
The site of work and the nature of the industry are strong predictors of HPD use.	(Edelson et al., 2009)	Annals of Occupational Hygiene	USA
Providing HPDs is suggested as a method of overcoming a lack of awareness in regards to OHL.	(Edward, Manohar, Somayaji, & Kallikkadan, 2016)	Indian Journal of Otology	India
Not all industries where workers could benefit from HPD use currently push HPD use.	(Dube, Ingale, & Ingale, 2011)	Noise & Health	India

Use of HPDs can make noise notches appear to be more defined on an audiogram by reducing threshold shifts in frequencies surrounding the area of greatest damage.	(Hsu, Wu, Chang, Lee, & Hsu, 2013)	The Laryngoscope	Taiwan
If HPDs are considered to be uncomfortable they are less likely to be utilised.	(Halevi-Katz, Yaakobi, & Putter-Katz, 2015)	Noise & Health	Israel
Day-to-day tasks may become normalised lowering the sense of susceptibility to noise, and reducing HPD use.	(Gates & Jones, 2007)	Public Health Nursing	USA
Force of habit, making the effort and laziness have all been described by employees as reasons they do not use HPDs.	(Gates & Jones, 2007)	Public Health Nursing	USA
Self-reported HPD use tends to over report HPD use.	(Griffin, Neitzel, Daniell, & Seixas, 2009)	Journal of Occupational and Environmental Hygiene	USA
Noise variability impacts the accuracy of self-reported HPD use.	(Griffin, Neitzel, Daniell, & Seixas, 2009)	Journal of Occupational and Environmental Hygiene	USA

The accuracy of self-reported HPD use declines over time.	(Griffin, Neitzel, Daniell, & Seixas, 2009)	Journal of Occupational and Environmental Hygiene	USA
Individuals may not use HPDs because they feel that hearing loss is an acceptable risk in their occupation.	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
Proper ear plug insertion training should be a part of a HCP.	(Huttunen, Sivonen, & Pöykkö, 2011)	Noise & Health	Finland
Attenuation qualities of HPDs do not impact HPD use.	(Huttunen, Sivonen, & Pöykkö, 2011)	Noise & Health	Finland
HPDs may be the only feasible intervention strategy in certain fields.	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
HPD use increases when individuals are aware of their levels of exposure.	(McTague et al., 2013)	International Journal of Audiology	USA
The effectiveness of HPDs varies widely and in dependent on many different variables.	(McTague et al., 2013)	International Journal of Audiology	USA
Advances in styles and convenience of HPDs may increase their usage.	(Neitzel et al., 2008)	American Journal of Industrial Medicine	USA

HPD use alone may not completely remove the risk of OHL.	(Hwang et al., 2001)	American Journal of Industrial Medicine	USA
Individuals may not begin to use HPDs until they have noticed a significant loss of hearing.	(Hwang et al., 2001)	American Journal of Industrial Medicine	USA
Individuals with hearing loss have greater communication difficulties while using HPDs than workers with normal hearing.	(Morata et al., 2005)	Ear & Hearing	USA
HPD usage is not always enforced.	(Morata et al., 2005)	Ear & Hearing	USA
There is a lack of awareness of different types of HPDs such as those with flat-attenuation or communication headsets.	(Morata et al., 2005)	Ear & Hearing	USA
HPDs are often seen as inconvenient to use.	(Morata et al., 2005)	Ear & Hearing	USA
A unilateral HPD can prevent hearing loss resultant from gunfire, whilst allowing communication with others.	(Moon, 2007)	Military Medicine	South Korea

Multiple layers of HPDs provide greater attenuation than one single device.	(Pelegrin, Canuet, Rodriguez, & Morales, 2015)	Noise & Health	Spain
HPDs need to be used consistently to provide the highest benefit.	(Themann et al., 2015)	Occupational and environmental medicine	USA
Employees may not know where to get HPDs.	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
Providing low-cost HPDs is a useful intervention for low income workers.	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
HPD initiatives should initially target industries with high levels of noise and low levels of HPD use.	(Tak, Davis, & Calvert, 2009)	American Journal of Industrial Medicine	USA
Individuals with hearing loss or tinnitus are more likely to use HPDs.	(Voaklander, Franklin, Challinor, Depczynski, & Fragar, 2009)	Journal of Agricultural Safety and Health	Australia
Earmuffs provide more protection at high noise levels while earplugs provide more protection at low noise levels.	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland

Level dependent HPDs can be used in intermittent noise to increase wear time.	(Williams, 2011)	Noise & Health	Australia

Note: HPD = hearing protection device, OHL = occupational hearing loss, HCP = hearing conservation programme, USA = United States of America

3.7 Legislation & Regulation

Seventeen studies that discussed legislation or regulatory approaches to curbing OHL met the eligibility criteria for inclusion in the scoping review (Cheung, 2004; Chou et al., 2009; Davies et al., 2008; Dobie, 2008; Fuente & Hickson, 2011; Gubata, Packnett, Feng, Cowan, & Niebuhr, 2013; Meinke & Morata, 2012; Morata et al., 2005; Mrena, Savolainen, Pirvola, & Ylikoski, 2004; Mrena et al., 2008; Ologe et al., 2008; Omokhodion et al., 2007; Rabinowitz et al., 2012; Sliwinska-Kowalska & Davis, 2012; Soalheiro et al., 2012; Tak et al., 2009; Verbeek et al., 2014).

The results displayed that regulation can be used to successfully decrease the burden of OHL (Dobie, 2008; Mrena et al., 2008), increase HPD use (Chou et al., 2009; Mrena et al., 2004), and to decrease noise exposure in the workplace (Chou et al., 2009; Verbeek et al., 2014). However, occupational noise legislation and regulations enforcing it are not universally in place around the world (Fuente & Hickson, 2011; Omokhodion et al., 2007). Systems for tracking OHL and noise exposure should be introduced internationally (Rabinowitz et al., 2012; Tak et al., 2009), while more must be done to stress the importance of hearing conservation in developing nations (Ologe et al., 2008; Omokhodion et al., 2007).

Table 8: Studies involving legislation and regulatory initiatives.

Theme	Reference	Journal	Study Location
The burden of OHL can be reduced by stricter enforcement of regulations.	(Dobie, 2008)	Ear & Hearing	USA
	(Mrena, Ylikoski, Kiukaanniemi, Mäkitie, & Savolainen, 2008)	International Journal of Audiology	Finland
Hearing loss caused before a change of regulations is a confounding factor when attempting to measure the effect of the change.	(Dobie, 2008)	Ear & Hearing	USA
	(Mrena, Ylikoski, Kiukaanniemi, Mäkitie, & Savolainen, 2008)	International Journal of Audiology	Finland
Regular inspection is important to ensure regulations are followed.	(Cheung, 2004)	Journal of Safety Research	Hong Kong
	(Ologe, Olajide, Nwawolo, & Oyejola, 2008)	The Journal of Laryngology and Otology	Nigeria
Regulation can be used to reduce noise exposure.	(Chou, Lai, & Kuo, 2009)	Noise & Health	Taiwan
	(Verbeek, Kateman, Morata, Dreschler, & Mischke, 2014)	International Journal of Audiology	Finland
Regulation can be used to successfully increase HPD use.	(Chou, Lai, & Kuo, 2009)	Noise & Health	Taiwan
	(Mrena, Savolainen, Pirvola, & Ylikoski, 2004)	International Journal of Audiology	Finland
Occupational noise legislation is not in place universally in all countries.	(Fuente & Hickson, 2011)	International Journal of Audiology	Australia
	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
The importance of hearing conservation should be stressed in developing countries.	(Ologe, Olajide, Nwawolo, & Oyejola, 2008)	The Journal of Laryngology and Otology	Nigeria
	(Omokhodion, Adeosun, & Fajola, 2007)	Noise & Health	Nigeria
Systems for tracking OHL and noise exposure should be developed at a governmental level, to an internationally-used standard.	(Rabinowitz et al., 2012)	Noise & Health	USA
	(Tak, Davis, & Calvert, 2009)	American Journal of Industrial Medicine	USA

Organisational regulation is the primary contributor to workers' use of HPDs.	(Cheung, 2004)	Journal of Safety Research	Hong Kong
Legislation is often not adequately enforced.	(Fuente & Hickson, 2011)	International Journal of Audiology	Australia
In some countries legislation varies depending on the age of the facilities.	(Fuente & Hickson, 2011)	International Journal of Audiology	Australia
Employees' are likely to over-report their HPD use if it is being reported to the regulatory authorities.	(Davies, Marion, & Teschke, 2008)	American Journal of Industrial Medicine	Canada
There is a lack of research determining the effectiveness of hearing conservation regulations.	(Davies, Marion, & Teschke, 2008)	American Journal of Industrial Medicine	Canada
Awards for hearing conservation can be used by regulatory bodies to disseminate strategies to reduce the risk of OHL, and encourage partnerships and cooperation within industries.	(Meinke & Morata, 2012)	International Journal of Audiology	USA
Stricter audiometric criteria for military enlistment reduces the chance of a disabling hearing loss later in a military career.	(Gubata, Packnett, Feng, Cowan, & Niebuhr, 2013)	Noise & Health	USA
Simply adhering to current regulations may not provide appropriate accommodation for workers with hearing loss.	(Morata et al., 2005)	Ear & Hearing	USA
Regulations for use of HPDs can significantly reduce cases of AAT.	(Mrena, Savolainen, Pirvola, & Ylikoski, 2004)	International Journal of Audiology	Finland
Improvements in noise legislation are necessary to reduce OHL.	(Sliwinska-Kowalska & Davis, 2012)	Noise & Health	Poland

Improvements in risk assessment are necessary in the development of noise regulations.	(Sliwinska-Kowalska & Davis, 2012)	Noise & Health	Poland
Policies should value self-reported changes in hearing as a method of early detection of hearing loss.	(Soalheiro et al., 2012)	Journal of Occupational Medicine and Toxicology	Brazil

Note: OHL = occupational hearing loss, HPD = hearing protection device, AAT = acute acoustic trauma, USA = United States of America.

3.8 Pharmacological otoprotection

Six studies concerning pharmacological methods of preventing or treating OHL met the eligibility criteria for the scoping review (Basner et al., 2014; Kapoor et al., 2011; Le Prell et al., 2011a; Lindblad, Rosenhall, Olofsson, & Hagerman, 2011; Moon, 2007; Sliwinska-Kowalska & Davis, 2012).

The most commonly-discovered themes indentified that antioxcidative medications show promise in reducing the damage caused by NIHL and AAT (Basner et al., 2014; Kapoor et al., 2011; Le Prell et al., 2011a; Sliwinska-Kowalska & Davis, 2012), and lessen the severity of TTS (Kapoor et al., 2011; Le Prell et al., 2011a; Sliwinska-Kowalska & Davis, 2012). Clinical human trials analysing the effects of these medications have been initiated (Basner et al., 2014; Sliwinska-Kowalska & Davis, 2012).

Table 9: Studies involving pharmacological otoprotection.

Theme	Citation	Journal	Study Location
Antioxidative medications have been shown to prevent or reduce NIHL & ATT in animal trials.	(Basner et al., 2014)	Lancet	USA
	(Kapoor et al., 2011)	Noise & Health	India
	(Sliwinska-Kowalska & Davis, 2012)	Noise & Health	Poland
	(Le Prell et al., 2011)	Noise & Health	Sweden
Antioxidative medications have been shown to attenuate TTS.	(Kapoor et al., 2011)	Noise & Health	India
	(Sliwinska-Kowalska & Davis, 2012)	Noise & Health	Poland
	(Le Prell et al., 2011)	Noise & Health	Sweden
Preventative and therapeutic drugs for NIHL are currently under development and expected to be available soon.	(Basner et al., 2014)	Lancet	USA
	(Sliwinska-Kowalska & Davis, 2012)	Noise & Health	Poland
Human clinical trials of otoprotective medication are currently underway.	(Basner et al., 2014)	Lancet	USA
	(Le Prell et al., 2011)	Noise & Health	Sweden
Hyperbaric oxygen therapy has been reported as an effective treatment for ATT.	(Moon, 2007)	Military Medicine	South Korea
Oral Steroidal Medication has been shown to be an effective method of treating AAT.	(Moon, 2007)	Military Medicine	South Korea
Antioxidative medications may give some protection from AAT.	(Lindblad, Rosenhall, Olofsson, & Hagerman, 2011)	Noise & Health	Sweden
Research into restoring cochlea function via stem cells is currently in early stages.	(Basner et al., 2014)	Lancet	USA

Note: NIHL = noise-induced hearing loss, AAT = acute acoustic trauma. TTS = temporary threshold shift, USA = United States of America.

3.9 Education

Nineteen studies discussing training or educational initiatives met the inclusion criteria and were included in the intervention scoping review (Arezes & Miguel, 2005; Cheung, 2004; Edward et al., 2016; Ehlers & Graydon, 2011; Fuente & Hickson, 2011; Gates & Jones, 2007; Goggin et al., 2008; Hong, Fiola, et al., 2013; Hong, Ronis, Lusk, & Kee, 2006; Hong et al., 2008; Jansen, Helleman, schler, & Laat, 2009; Jenkins et al., 2007; Meinke & Morata, 2012; Morata et al., 2005; Neitzel et al., 2008; Pouryaghoub, Mehrdad, & Mohammadi, 2007; Stephenson, Shaw, Stephenson, & Graydon, 2011; Trabeau, Neitzel, Meischke, Daniell, & Seixas, 2008; Williams, Purdy, Murray, LePage, & Challinor, 2004).

The most common themes discovered during the review were that educational initivatives can be successfully used to increase the use of HPDs in the workplace (Gates & Jones, 2007; Morata et al., 2005; Neitzel et al., 2008; Trabeau et al., 2008). Training programmes should utilise the results of audiometric monitoring (Hong et al., 2008; Jenkins et al., 2007; Morata et al., 2005), and stress the importance of consistent and correct HPD use (Hong et al., 2008; Jansen, Helleman, Schler, & Laat, 2009; Morata et al., 2005).

Table 10: Studies involving educational initiatives.

Theme	Reference	Journal	Study Location
Educational interventions can be successful in increasing HPD use, including in industries that are considered difficult to regulate.	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Morata et al., 2005)	Ear & Hearing	USA
	(Trabeau, Neitzel, Meischke, Daniell, & Seixas, 2008)	American Journal of Industrial Medicine	USA
	(Neitzel et al., 2008)	American Journal of Industrial Medicine	USA
Results of audiometric monitoring should be incorporated into educational programmes.	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
	(Morata et al., 2005)	Ear & Hearing	USA
	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
Training programmes should stress the importance of consistent and correct HPD use.	(Morata et al., 2005)	Ear & Hearing	USA
	(Jansen, Helleman, Schler, & Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
	(Hong, Samo, Hulea, & Eakin, 2008)	Journal of Occupational and Environmental Hygiene	USA
A sustained educational effort over time is more effective than a solitary intervention.	(Goggin et al., 2008)	The Australian and New Zealand Journal of Audiology	Australia
	(Jansen, Helleman, Schler, & Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
Knowledge of the dangers of OHL alone does not change an individual's hearing protective behaviours.	(Goggin et al., 2008)	The Australian and New Zealand Journal of Audiology	Australia
	(Cheung, 2004)	Journal of Safety Research	Hong Kong
Many employees have little understanding of OHL and its prevention.	(Edward, Manohar, Somayaji, & Kallikkadan, 2016)	Indian Journal of Otology	India

	(Fuente & Hickson, 2011)	International Journal of Audiology	Australia
Education significantly effects perceived susceptibility to OHL, and overall perception of noise.	(Williams, Purdy, Murray, LePage, & Challinor, 2004)	Australian Journal of Rural Health	Australia
	(Trabeau, Neitzel, Meischke, Daniell, & Seixas, 2008)	American Journal of Industrial Medicine	USA
Educational campaigns that target organisations rather than individuals may encourage the reduction of ambient noise levels.	(Goggin et al., 2008)	The Australian and New Zealand Journal of Audiology	Australia
Research is needed to determine how interpersonal variables such as activity types, age, work experience and education impact the success of training initiatives.	(Arezes & Miguel, 2005)	Human Factors: The Journal of the Human Factors and Ergonomics Society	Portugal
Educational interventions that are tailored to employees' needs facilitate a significantly greater initial increase in HPD use.	(Hong, Ronis, Lusk, & Kee, 2006)	International Journal of Behavioral Medicine	USA
Educational sessions should be paired with regular booster interventions to reinforce behavioural changes.	(Hong, Ronis, Lusk, & Kee, 2006)	International Journal of Behavioral Medicine	USA
Educational programmes cannot be successful without overcoming any barriers to individual participation.	(Hong, Fiola, & Feld, 2013)	Workplace Health and Safety	USA
Ensuring participation in an educational intervention requires collaboration with key stake holders in the industry.	(Hong, Fiola, & Feld, 2013)	Workplace Health and Safety	USA
Offering educational programmes online is a successful method for increasing enrolment.	(Hong, Fiola, & Feld, 2013)	Workplace Health and Safety	USA

Organisations can successfully partner together to raise awareness and provide education in hearing conversation for industries that are difficult to regulate.	(Ehlers & Graydon, 2011)	Noise & Health	USA
Employers may have incorrect perceptions of the feasibility or cost of interventions.	(Jenkins, Stack, Earle-Richardson, Scofield, & May, 2007)	Journal of Agricultural Safety and Health	USA
Incorporating employees with hearing loss as role models into training programmes can be a powerful endorsement of the use of HPDs.	(Morata et al., 2005)	Ear & Hearing	USA
As smoking can accelerate NIHL, smokers should be educated on the dangers of smoking combined with noise exposure as part of educational initiatives.	(Pouryaghoub, Mehrdad, & Mohammadi, 2007)	BMC Public Health	Iran
Award programmes for workplaces displaying excellence in hearing loss prevention can be used to disseminate information about effective intervention strategies.	(Meinke & Morata, 2012)	International Journal of Audiology	USA
Training is required to ensure that workers take a more positive approach to reducing noise exposure.	(Williams, Purdy, Murray, LePage, & Challinor, 2004)	Australian Journal of Rural Health	Australia
Educational initiatives should include information about symptoms that may help individuals identify a change in their hearing (e.g., tinnitus, hyperacusis, TTS)	(Jansen, Helleman, Schler, & Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
Educational initiatives can be successfully administered in either group or one-on-one environments.	(Stephenson, Shaw, Stephenson, & Graydon, 2011)	Noise & Health	USA

It is recommended that education initiatives be tailored to focus on the target audience's attitudes and beliefs about the use of HPDs.	(Stephenson, Shaw, Stephenson, & Graydon, 2011)	Noise & Health	USA

Note: HPD = hearing protection device, OHL = occupational hearing loss, TTS = temporary threshold shift, USA = United States of America.

4.0 Results of the Outcome Measures Scoping Review

4.1 Included studies

The results of the systematic search uncovered studies that utilized: participants' attitudes and beliefs towards hearing loss prevention, shifts in participants' audiometric thresholds, blood pressure, cost effectiveness of HCPs, prevalence of falls in seniors, HPD usage, presence of hyperacusis, prevalence of OHL, level of noise exposure, number of AAT incidents, number of compensation claims lodged, hearing related occupational difficulties, prevalence of non-hearing related occupational injuries, change in otoacoustic emissions, use of preventative actions, self-reported hearing loss symptoms, source of income, cases of tinnitus, and work readiness of participants as outcome measures. In total, 93 studies that met the inclusion criteria of this scoping review were discovered. Some studies utilized multiple outcome measures and thus have been placed under multiple subheadings in this chapter. A flowchart displaying the inclusion and exclusion pathways of this review can be seen below in figure 2.

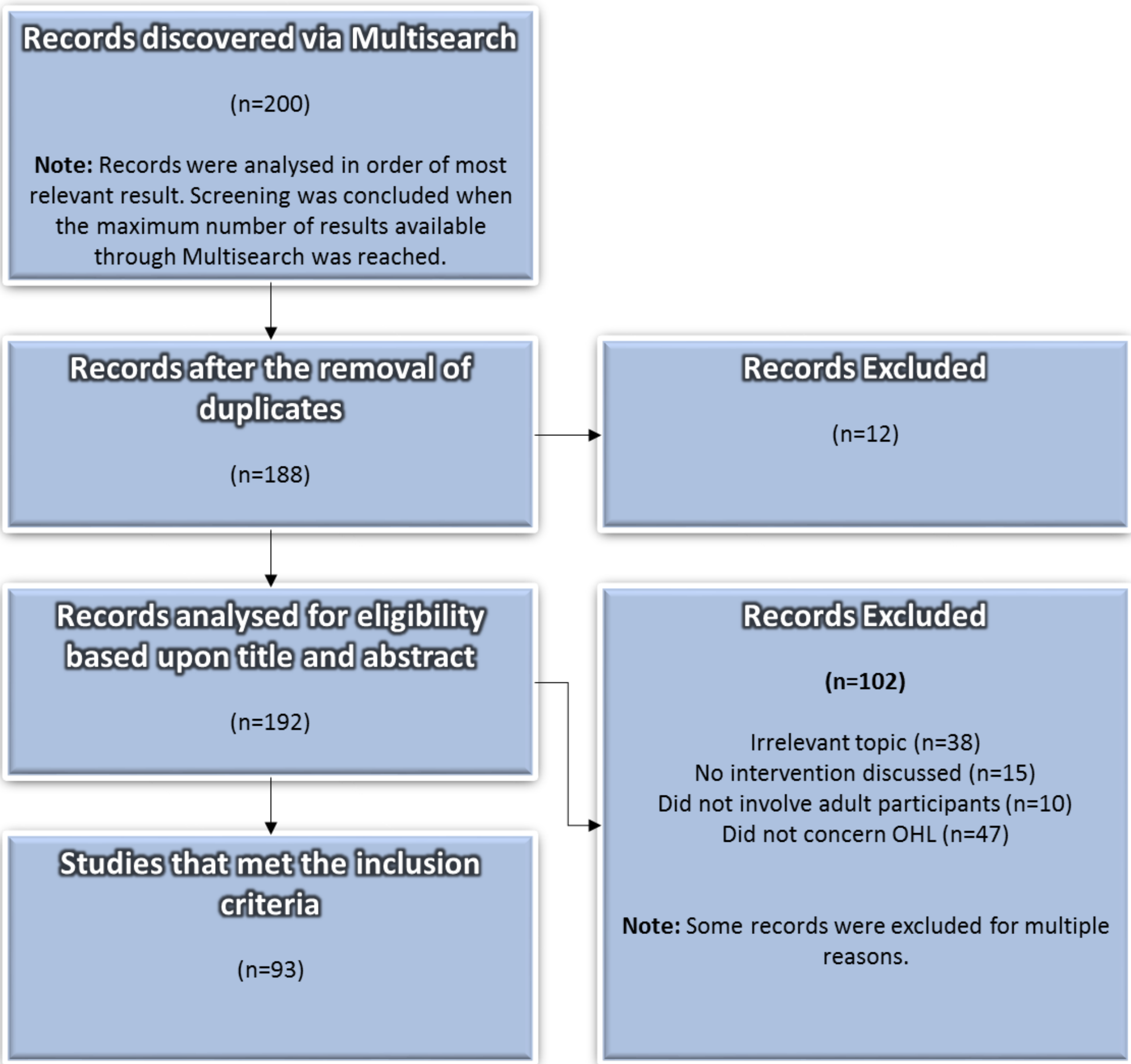

Figure 2: Inclusion and exclusion pathways of the outcome measures scoping review.

4.3 Summary of Outcome Measures

The most commonly-utilised outcome measure was changes in the participants' audiometric thresholds as measured by pure-tone audiometry (Aliabadi et al., 2015; Berg, Pickett, Linneman, Wood, & Marlenga, 2014; Chang, Chen, Lien, & Sung, 2006; Chou et al., 2009; Collee et al., 2011; Cruickshanks et al., 2010; Davies et al., 2008; Dube et al., 2011; Ecob et al., 2008; Dib, Silva, Morais, & Trevisani, 2008a; Fransen et al., 2008; Guest et al., 2010; Halevi-Katz et al., 2015; Hope, Luxon, & Bamiou, 2013; Hughes & Hunting, 2013; Huh, Choi, & Moon, 2016; Humann, Sanderson, Gerr, Kelly, & Merchant, 2012; Jansen, Helleman, Schler, & de Laat, 2009; Le Prell et al., 2011b; Lie, Skogstad, Johnsen, Engdahl, & Tambs, 2014; Lin et al., 2009; Marlenga et al., 2012; Marshall et al., 2009; Masilamani, Rasib, Darus, & Ting, 2014; Masterson, Deddens, Themann, Bertke, & Calvert, 2015; Masterson et al., 2013; McBride & Williams, 2001; Mehrparvar et al., 2015; Moon, 2007; Nomura, Nakao, & Yano, 2005; Oestenstad et al., 2008; Onder, Onder, & Mutlu, 2012; Picard et al., 2008; Rabinowitz et al., 2007; Rubak et al., 2008; Schaal, Slagley, Zreiqat, & Paschold, 2017; Seixas et al., 2005; Seixas et al., 2012; Smedje, Lundén, Gärtner, Lundgren, & Lindgren, 2011; Tambs, Hoffman, Borchgrevink, Holmen, & Engdahl, 2006; Tao et al., 2013; Wells et al., 2015; Whittaker, Robinson, Acharya, Singh, & Smith, 2014; Wild, Brewster, & Banerjee, 2005; Wilson, Darby, Tolle, & Sever, 2002; Wooles, Mulheran, Bray, Brewster, & Banerjee, 2015). The majority of these studies utilised primary audiometric data collected during the study itself, however some secondary data was collected through previous studies or as the result of historical audiometric monitoring (Fransen et al., 2008; Hughes & Hunting, 2013; Huh et al., 2016; E Masterson et al., 2015; E. Masterson et al., 2013; McBride & Williams, 2001; Picard et al., 2008).

The second most-common outcome measure was noise exposure assessed though dosimetry, site measurements or exposure predictions based on industry norms (Aliabadi et al., 2015; Daniell et al., 2006; Hughes & Hunting, 2013; Humann et al., 2012; Marlenga et al., 2012; McBride & Williams, 2001; Picard et al., 2008; Rabinowitz, Galusha, Dixon-Ernst, Clougherty, & Neitzel, 2013; Rabinowitz et al., 2007; Schaal et al., 2017; Seixas et al., 2005; Smedje et al., 2011; Tambs et al., 2006; Tao et al., 2013; Williams et al., 2015).

The third most-common outcome measure was HPD usage (Arezes & Miguel, 2005; Gates & Jones, 2007; Griffin et al., 2009; Hong, Chin, L Fiola, et al., 2013; Hong, Chin, & Ronis, 2013; Hong et al., 2006; Huttunen et al., 2011; Seixas et al., 2005; Williams, Purdy, Murray, Dillon, et al., 2004). In most cases this was self-reported; however one study also measured HPD usage with objective methods (Griffin et al., 2009).

The following table contains the full results of the systematic search categorised by the outcome measures that were found. Brief descriptions of the outcome measures can be found below each heading to provide clarity. The total number of studies using each measure can be found in parentheses next to the outcome measures name.

Table 11: Outcome measures utilised.

Outcome Measure	Reference	Journal	Study Location
Audiometric Threshold Shifts (46)* *Measured using pure-tone audiometry.*	(Aliabadi et al., 2015)	International Archives of Occupational and Environmental Health	Iran
	(Berg et al., 2014)	Noise & Health	USA
	(Chang et al., 2006)	Environmental Health Perspectives	Taiwan
	(Chou et al., 2009)	Noise & Health	Taiwan
	(Collee et al., 2011)	Noise & Health	Belgium
	(Cruickshanks et al., 2010)	Hearing Research	USA
	(Davies et al., 2008)	American Journal of Industrial Medicine	Canada
	(Dube et al., 2011)	Noise & Health	India
	(Ecob et al., 2008)	International Journal of Audiology	United Kingdom
	(El Dib et al., 2008a)	BMC Public Health	Brazil
	(Fransen et al., 2008)	Journal of the Association for Research in Otolaryngology	Belgium/Finland
	(Guest et al., 2010)	American Journal of Industrial Medicine	Australia
	(Halevi-Katz et al., 2015)	Noise & health	Israel
	(Hope et al., 2013)	Journal of Laryngology and Otology	United Kingdom
	(Hughes & Hunting, 2013)	Noise & Health	USA
	(Huh et al., 2016)	PLoS ONE	South Korea
** Each number in parentheses in the left-hand column refers to the total number of studies using each individual outcome measure.*	(Humann et al., 2012)	American Journal of Industrial Medicine	USA
	(Jansen, Helleman, schler, & de Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
	(Le Prell et al., 2011b)	Noise & Health	Sweden
	(Lie et al., 2014)	British Medical Journal	Norway

(Audiometric Thresholds cont.)	(Lin et al., 2009)	Hearing Research	Taiwan
	(Marlenga et al., 2012)	Occupational and Environmental Medicine	USA
	(Marshall et al., 2009)	Accident Analysis and Prevention	USA
	(Masilamani et al., 2014)	Asia-Pacific Journal of Public Health	Malaysia
	(Masterson et al., 2015)	American Journal of Industrial Medicine	USA
	(Masterson et al., 2013)	American Journal of Industrial Medicine	USA
	(McBride & Williams, 2001)	Occupational and Environmental Medicine	United Kingdom
	(Mehrparvar et al., 2015)	Noise & health	Iran
	(Moon, 2007)	Military Medicine	South Korea
	(Nomura et al., 2005)	International Archives of Occupational and Environmental Health	Japan
	(Oestenstad et al., 2008)	Military Medicine	USA
	(Onder et al., 2012)	Environmental Monitoring and Assessment	Turkey
	(Picard et al., 2008)	Accident Analysis and Prevention	Canada
	(Rabinowitz et al., 2007)	Occupational and Environmental Medicine	USA
	(Rubak et al., 2008)	International Journal of Audiology	Denmark
	(Schaal et al., 2017)	American Journal of Industrial Medicine	USA
	(Seixas et al., 2005)	Occupational and Environmental Medicine	USA

(Audiometric Thresholds cont.)	(Seixas et al., 2012)	Occupational and Environmental Medicine	USA
	(Smedje et al., 2011)	Noise & Health	Sweden
	(Tambs et al., 2006)	International Journal of Audiology	USA
	(Tao et al., 2013)	Noise & Health	China
	(Wells et al., 2015)	Noise & Health	USA
	(Whittaker et al., 2014)	Journal of Laryngology and Otology	Nepal
	(Wild et al., 2005)	Clinical Otolaryngology	United Kingdom
	(Wilson et al., 2002)	Journal of Dental Hygiene	USA
	(Wooles et al., 2015)	The Journal of Laryngology and Otology	United Kingdom
	(Ayçiçek, Sargın, Kenar, & Dereköy, 2009)	European Archives of Oto-Rhino-Laryngology	Turkey
Noise Exposure (15) *Measured via dosimetry, site noise measurement or predictions based on industry norms.*	(Aliabadi et al., 2015)	International Archives of Occupational and Environmental Health	Iran
	(Daniell et al., 2006)	Occupational and Environmental Medicine	USA
	(Hughes & Hunting, 2013)	Noise & Health	USA
	(Humann et al., 2012)	American Journal of Industrial Medicine	USA
	(Marlenga et al., 2012)	Occupational and Environmental Medicine	USA
	(McBride & Williams, 2001)	Occupational and Environmental Medicine	United Kingdom
	(Picard et al., 2008)	Accident Analysis and Prevention	Canada
	(Rabinowitz et al., 2013)	Occupational and Environmental	USA

		Medicine	
(Noise Exposure cont.)	(Rabinowitz et al., 2007)	Occupational and Environmental Medicine	USA
	(Schaal et al., 2017)	American Journal of Industrial Medicine	USA
	(Seixas et al., 2005)	Occupational and Environmental Medicine	USA
	(Smedje et al., 2011)	Noise & Health	Sweden
	(Tambs et al., 2006)	International Journal of Audiology	USA
	(Tao et al., 2013)	Noise & Health	China
	(Williams et al., 2015)	Australian Journal of Rural Health	Australia
HPD Usage (9) *Measured via user self-reports, or objectively via observation.*	(Arezes & Miguel, 2005)	The Journal of the Human Factors and Ergonomics Society	Portugal
	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Griffin et al., 2009)	Journal of Occupational and Environmental Hygiene	USA
	(Hong, Chin, Fiola, et al., 2013)	American Journal of Industrial Medicine	USA
	(Hong, Chin, & Ronis, 2013)	International Journal of Behavioral Medicine	USA
	(Hong et al., 2006)	International Journal of Behavioral Medicine	USA
	(Huttunen et al., 2011)	Noise & Health	Finland
	(Seixas et al., 2005)	Occupational and Environmental Medicine	USA
	(Williams, Purdy, Murray, Dillon, et al., 2004)	Noise & Health	Australia
Incidences of OHL (7) *Number of individuals with OHL within the study sample.*	(Chang et al., 2006)	Environmental Health Perspectives	Taiwan
	(Choi & Kim, 2014)	PLoS One	South Korea
	(Masterson, Themann,	American Journal of Industrial	USA

(Incidences of OHL cont.)	Luckhaupt, Li, & Calvert, 2016)	Medicine	
	(McCullagh, Raymond, Kerr, & Lusk, 2011b)	Noise & Health	USA
	(Meuer & Hiller, 2015)	Noise & health	Germany
	(Schink, Kreutz, Busch, Pigeot, & Ahrens, 2014)	Occupational and Environmental Medicine	Germany
	(Selander et al., 2016)	Environmental Health Perspectives	Sweden
Otoacoustic Emissions (7) *Changes in the participants' otoacoustic emissions.*	(Hope et al., 2013)	Journal of Laryngology and Otology	United Kingdom
	(Jansen, Helleman, schler, & de Laat, 2009)	International Archives of Occupational and Environmental Health	Holland
	(Le Prell et al., 2011b)	Noise & Health	Sweden
	(Marshall et al., 2009)	Accident Analysis and Prevention	USA
	(Mehrparvar et al., 2015)	Noise & health	Iran
	(Seixas et al., 2005)	Occupational and Environmental Medicine	USA
	(Wooles et al., 2015)	The Journal of laryngology and otology	United Kingdom
Self-Reported Hearing Loss Complaints (7) *Participants reported having difficulties hearing in a variety of circumstances commonly-related to hearing loss, or believed their hearing had deteriorated.*	(Hasson, Theorell, Wallén, Leineweber, & Canlon, 2011)	BMC Public Health	Sweden
	(Lazar, Kauer, & Rowe, 2015)	Journal of Dental Hygiene	USA
	(Messano & Petti, 2012)	Journal of Dentistry	Italy
	(Meuer & Hiller, 2015)	Noise & health	Germany
	(Palmer, Griffin, Syddall, & Coggon, 2004)	Occupational and Environmental Medicine	United Kingdom
	(Palmer et al., 2002)	Occupational and Environmental Medicine	United Kingdom
	(Wells et al., 2015)	Noise & Health	USA

Tinnitus (7) *Participant reported experiencing tinnitus*	(Engdahl, Krog, Kvestad, Hoffman, & Tambs, 2012)	British Medical Journal	Norway
	(Hasson et al., 2011)	BMC Public Health	Sweden
	(Masterson et al., 2016)	American Journal of Industrial Medicine	USA
	(Meuer & Hiller, 2015)	Noise & health	Germany
	(Moon, 2007)	Military Medicine	South Korea
	(Rubak et al., 2008)	International Journal of Audiology	Denmark
	(Selander et al., 2016)	Environmental Health Perspectives	Sweden
Attitudes and Beliefs towards Hearing Loss prevention (6) *Measured via surveys or questionnaires.*	(Arezes & Miguel, 2005)	The Journal of the Human Factors and Ergonomics Society	Portugal
	(Cheung, 2004)	Journal of Safety Research	Hong Kong
	(Gates & Jones, 2007)	Public Health Nursing	USA
	(Murray-Johnson et al., 2004)	Health Education & Behavior	USA
	(Quick et al., 2008)	Journal of Safety Research	USA
	(Stephenson et al., 2011)	Noise & Health	USA
Occupational Injury (Non-hearing related) (4) *Number of occupational injuries participants experienced excluding those related to their auditory system.*	(Cantley, Galusha, Cullen, Dixon-Ernst, Rabinowitz, et al., 2015)	Scandinavian Journal of Work, Environment & Health	USA
	(Cantley, Galusha, Cullen, Dixon-Ernst, Tessier-Sherman, et al., 2015)	International Journal of Audiology	USA
	(Kim, Yoon, Roh, & Won, 2016)	Noise & Health	South Korea
	(Picard et al., 2008)	Accident Analysis and Prevention	Canada

Noise-induced hearing loss Injury (2) *Injuries directly caused by exposure to noise, e.g. AAT, perforations, TTS, impulse related tinnitus.*	(Cantley, Galusha, Cullen, Dixon-Ernst, Rabinowitz, et al., 2015)	Scandinavian Journal of Work, Environment & Health	USA
	(Helfer et al., 2005)	American Journal of Audiology	USA
Number of Compensation Claims Lodged (2) *The number of compensation claims of OHL submitted to relevant authorities.*	(McCall & Horwitz, 2004)	American Journal of Industrial Medicine	USA
	(Radi, Benke, Schaafsma, & Sim, 2016)	Australian and New Zealand Journal of Public Health	Australia
Blood Pressure (1) *Measurements of the participants systolic blood pressure (SBP) and diastolic blood pressure (DBP)*	(Chen et al., 2017)	BMC Public Health	China
Cost Effectiveness of HCPs (1) *Measures through a series of simulations run using an outcome modelling strategy developed by the US Department of Defense.*	(Helfer, Shields, & Gates, 2000)	American Journal of Audiology	USA
Falls (1) *Incidence of falls in seniors who have an OHL.*	(Girard et al., 2014)	Canadian Journal on Aging / La Revue Canadienne du Vieillissement	Canada
Hyperacusis (1) *Number of participants who complain of symptoms of hyperacusis.*	(Meuer & Hiller, 2015)	Noise & health	Germany

Occupational Difficulties (Related to hearing loss) (1) *Measured using the Amsterdam Checklist for Hearing and Work which is designed to investigate relations between hearing and work.*	(Kramer, Kapteyn, & Houtgast, 2006)	International Journal of Audiology	Netherlands
Preventative Actions taken (1) *Changes in the amount and type of action being taken by individuals to prevent OHL. Assessed via survey.*	(Williams, Purdy, Murray, Dillon, et al., 2004)	Noise & Health	Australia
Source of Income (1) *Determining common sources of income for adults of working age with OHL.*	(Pierre, Fridberger, Wikman, & Alexanderson, 2012)	BMC Public Health	Sweden
Work Readiness (1) *Measured using a Chinese version of Lam's Assessment of stage of employment readiness.*	(Li, Li-Tsang, Lee, Lee, & Lam, 2006)	Journal of Occupational Rehabilitation	China

Note: HPD = hearing protection device, OHL = occupational hearing loss, HCP = hearing conservation programme, USA = United States of America

5.0 Discussion

The aim of this study was to develop a cohesive roadmap for future research into the field of OHL. This was achieved by identifying and summarising the interventional strategies that are discussed in the literature, and which outcome measures have been used to assess their efficacy. Through achieving this it is hoped to provide a starting point, identifying holes in our understanding and how future studies can be developed.

5.1 Hearing Conservation Programmes

The results of this study clearly show that HCPs can be used to successfully reduce the impact of OHL (Davies et al., 2008; Hong, 2005; McCullagh et al., 2011a; Mihailovic et al., 2011; Mrena et al., 2007; Rabinowitz et al., 2007; Rubak et al., 2006). However, not all workplaces where employees were exposed to dangerous noise levels utilized HCPs, and those that did often neglected vital components, or gave priority to HCP components that belong further down the hierarchy of control (Daniell et al., 2006; Hong, 2005; Hong et al., 2008; Lao et al., 2013; McCullagh et al., 2011a).

Employee compliance with HCPs was found to be higher in workplaces where the HCP was the most comprehensive (Daniell et al., 2006), containing all the components of a HCP as described in chapter 1, and being strictly enforced by management (Verbeek et al., 2014). The presence of a HCP does not necessarily mean that there is no risk of OHL amongst employees (Trost & Shaw, 2007; Verbeek et al., 2014). Typical HCPs utilize an exposure limit of 85dBLeq; however, OHL can occur at levels below this. More research is required to study the risks of OHL in positions that do not reach the exposure limit of the HCPs (P Rabinowitz et al., 2007; Verbeek et al., 2014). Noise conditions in the workplace may change over time. This necessitates regular re-evaluation of noise conditions to ensure that the HCP is being implemented effectively, and improved where needed (Helfer et al., 2005; Muhr & Rosenhall, 2011;

Oestenstad et al., 2008; Trost & Shaw, 2007). Involvement in an HCP should occur at all levels of an organisation. It is important for middle management to be involved in leadership roles within the HCP (Azizi, 2010b; Helfer et al., 2005), and frontline staff are consulted during evaluations to ensure the programme fulfils their needs, and does not hinder their performance (Prince et al., 2004).

Although at-risk industries should be considered a priority when encouraging the implementation of HCPs (Tak et al., 2009), it is important to recognise that there are individuals exposed to dangerous levels of noise in fields that are not traditionally considered to be high risk such as cleaners, kitchen staff and retail personnel (Tak et al., 2009). Hearing conservation programmes focusing on audiometric monitoring may be a valuable tool after the cessation of employment to ensure that further impairment due to recreational hearing loss is not occurring in addition to a historical OHL (Saunders & Griest, 2009). Hearing conservation programmes are often absent in developing countries due to lack of facilities or resources (Ologe, Olajide, Nwawolo, & Oyejola, 2008; Omokhodion, Adeosun, & Fajola, 2007). Self-reported hearing questionnaires may be an alternative to objective testing in these conditions (Ahmed et al., 2004).

5.2 Educational Initiatives

Educational interventions have been shown to be an effective method of encouraging consistent and correct HPD usage amongst employees (Gates & Jones, 2007; O Hong et al., 2008; Jansen, Helleman, schler, & Laat, 2009; Morata et al., 2005; Neitzel et al., 2008; Trabeau et al., 2008). This appears to be true even in industries that are considered difficult to regulate like construction (Neitzel et al., 2008; Trabeau et al., 2008). Additionally, education on the dangers of noise and OHL can encourage employees to reduce their noise exposure by illustrating that they are susceptible to OHL, thereby increasing their awareness of noise in the work environment (Trabeau et al., 2008; Williams, Purdy, Murray, LePage, et al., 2004). Despite these benefits many employees do not currently know about OHL or the importance of its prevention (Edward et al., 2016; Fuente & Hickson, 2011).

Educational approaches to hearing conservation have been shown to be most effective when consistently reinforced (Goggin et al., 2008; Jansen, Helleman, schler, & Laat, 2009). This can be achieved through regular booster interventions designed to remind participants of the importance of hearing protection (Hong et al., 2006).

Educational initiatives cannot be successful if they do not overcome barriers to participation such as workplace culture, or individual attitudes towards hearing loss (Hong, Fiola, et al., 2013). Barriers can be overcome by delivering the programme with collaboration from key stakeholders such as employers, workers' unions, and related industrial organisations (Ehlers & Graydon, 2011; Hong, Fiola, et al., 2013). The benefit of educational initiatives does not appear to be dependent on the modality of their delivery as programmes are effective when delivered one-on-one, in group situations or online (Hong, Fiola, et al., 2013; Stephenson et al., 2011). This suggests that participation can be increased by making the programme as convenient as possible for participants.

To maximise their effect, programmes should be relatable to individual employees and relevant to the field of work. This may be achieved by providing information about audiometric results, tinnitus or other related symptoms that employees may experience, or including testimony from co-workers who experience the impacts a hearing loss (Hong et al., 2008; Jansen, Helleman, Schler, & Laat, 2009; Jenkins et al., 2007; Morata et al., 2005). Individually-tailored educational programmes may show greater benefits in terms of motivation to change and retention of information; however more research needs to be conducted regarding the best way to tailor programmes (Hong et al., 2006; Stephenson et al., 2011).

Educational initiatives can also be used at management levels within companies to encourage the reduction of noise exposure in the workplace (Goggin et al., 2008). As employers are often hesitant to commit to new strategies because of perceived costs, education programmes should include information about cost-effective noise reduction (Jenkins et al., 2007). Awards for excellence in the workplace have proved an effective way of encouraging corporate involvement and disseminating information about OHL (Meinke & Morata, 2012).

5.3 Pharmacological Otoprotection

Preventative, and therapeutic drugs to reduce the risk of, and/or prevent OHL are currently under development and are expected to be available in the near future (Basner et al., 2014; Sliwinska-Kowalska & Davis, 2012). Antioxidative medication (Kapoor et al., 2011; Le Prell et al., 2011a; Sliwinska-Kowalska & Davis, 2012), hyperbaric oxygen therapy and steroidal medication (Moon, 2007) have all shown promise in reducing NIHL and AAT. Currently researchers are assessing whether stem cell treatments can potentially restore function to a damaged cochlea (Basner et al., 2014).

5.4 Administrative Control

Reducing the number of hours an employee is working in a noisy environment can be a successful method of reducing OHL in occupations when noise reduction at the source is not a viable option (Karimi et al., 2010). This can be achieved through monitoring employees' noise exposure (McTague et al., 2013), and scheduling shifts to allow sufficient time for the employee's auditory system to recover (Chou et al., 2009; Daniell et al., 2002).

Measurements of ambient noise within the work environment should regularly be collected to identify workstations that constitute a risk of OHL, and identify changes in noise levels (Daniell et al., 2002; Pelegrin et al., 2015; Prince et al., 2004). Many companies either do not regularly take these measurements, or fail to keep records of noise levels (Daniell et al., 2002; Prince et al., 2004). Although employees often have little understanding of the risk of OHL (Daniell et al., 2002; Prince et al., 2004), research has found that they will voluntarily monitor their exposure levels if equipment is provided (McTague et al., 2013). Providing feedback to employees on their daily noise dosage allows them to take steps to avoid excess exposure (McTague et al., 2013).

5.5 Engineering Controls

Engineering controls have been shown to be the most effective method of reducing occupational noise exposure and OHL (Nelson, Nelson, Concha-Barrientos, et al., 2005; Verbeek et al., 2014). Engineering control strategies should be an important part of all HCPs (Daniell et al., 2006; Hong et al., 2016; Mihailovic et al., 2011), and given priority over all other intervention strategies (Gates & Jones, 2007; Hwang et al., 2001; Mihailovic et al., 2011). Engineering controls are often overlooked in favour of interventional approaches located further down the hierarchy of control (Daniell et al., 2006; Voaklander et al., 2009). This is particularly evident in smaller organisations (Daniell et al., 2006). This is often due to the fact that engineering controls can be difficult to implement in certain industries (Hong, 2005; Sliwinska-Kowalska & Davis, 2012), and are often seen as price prohibitive (Gates & Jones, 2007; Hong, 2005). Further research is needed to evaluate the success of different engineering interventions (Verbeek et al., 2014).

5.6 Audiometric Monitoring

Regular audiometric monitoring of employees can be used to reduce the risk of OHL (Dube et al., 2011; Hong, 2005; Karimi et al., 2010; Ologe et al., 2006; Ologe et al., 2008; Pelegrin et al., 2015; Soalheiro et al., 2012). There are a wide variety of different protocols and tests that enable an employee's hearing to be audiometrically evaluated. In addition to standard audiometry (250Hz – 8 kHz), high-frequency audiometry (Mehrparvar et al., 2011) and self-administered audiometric screening may be employed (Hong, 2005). Distortion product otoacoustic emissions (DPOAE) have been shown to be effective in evaluating vulnerability to noise (Job et al., 2009; Ologe et al., 2006).

Despite the importance of consistent monitoring many companies and industries do not monitor their employees hearing (Daniell et al., 2002; Hong, 2005; Ologe et al., 2006). This may be due to a lack of facilities (Ologe et al., 2006), or administrative difficulties in the implementation of a monitoring system. For instance, it may be difficult to consistently test employees in industries where workers are often on short-term contracts or are independent contractors (Hong, 2005). Public audiometric screening events may be a valuable tool to reach populations who are not being regularly monitored (Jenkins et al., 2007).

Employees often do not understand the results of their audiometric assessments (Daniell et al., 2002; McCullagh et al., 2011a; Pelegrin et al., 2015). This may hinder their ability to proactively reduce their exposure levels. Although an important aspect of a HCP, monitoring alone cannot be used to show the programme's effectiveness (Prince et al., 2004).

5.7 Legislature

Proper regulation can encourage consistent HPD use can lead to a reduction in cases of OHL and AAT (Dobie, 2008; Mrena et al., 2008; Sliwinska-Kowalska & Davis, 2012). It has been shown that proper enforcement of company polices in relation to noise, is the primary contributor to the correct usage of HPDs (Chou et al., 2009; Mrena et al., 2004). Company regulations are generally informed by governmental legislation however, legislation is not always in place, or correctly enforced (Fuente & Hickson, 2011). This is particularly evident in developing countries (Ologe et al., 2008; Omokhodion et al., 2007). Regular inspection by regulatory bodies is vital to ensure that legislation is being adhered to in the workplace (Cheung, 2004; Ologe et al., 2008). It has been shown that employees will over over-represent their HPD usage if it is to be reported to regulatory bodies (Davies et al., 2008).

Governmental legislation often does not consider the special needs of workers with hearing losses in terms of communication and safety (Morata et al., 2005). Legislation is often a one-size-fits-all solution based around the needs of employees with normal hearing. It is important that governmental legislation is consistently evaluated, and that risk assessments are regularly performed to better understand risks to workers in different situations (Cheung, 2004; Ologe et al., 2008; Sliwinska-Kowalska & Davis, 2012). Subjective information reported by employees about their hearing should be seen as just as valid as audiometric data whilst evaluating legislation (Soalheiro et al., 2012). It has been suggested that to encourage global co-operation in reducing OHL, an international standard for reporting OHL cases should be developed (Rabinowitz et al., 2012; Tak et al., 2009). This may help to address a lack of research into the effectiveness of regulatory efforts by allowing comparisons to be easily drawn on a global scale (Davies et al., 2008).

5.8 Hearing Protective Devices

HPDs have been shown to successfully reduce the risk of OHL (Chou et al., 2009; Hong, 2005; Marlenga et al., 2012; Mrena et al., 2008; Pelegrin et al., 2015; Solanki et al., 2012;

Themann et al., 2015; Verbeek et al., 2014). However, not all employees who are exposed to excessive noise in the workplace regularly and consistently use HPDs (Daniell et al., 2006; Gates & Jones, 2007; Halevi-Katz et al., 2015; Hong, 2005; Hong, Chin, Fiola, et al., 2013; Hong, Fiola, et al., 2013; Hong et al., 2008; Jenkins et al., 2007; Marlenga et al., 2012; McTague et al., 2013; Ologe et al., 2005; Omokhodion et al., 2007; Rabinowitz et al., 2007; Solanki et al., 2012; Tak et al., 2009; Zander & Richter, 2008). HPDs are not universally-encouraged across all fields that could benefit from their usage such as the cotton industry, and firefighting (Dube et al., 2011; Hong et al., 2008). These trends lead to the site of work and the nature of the industry being strong predictors of HPD use (Edelson et al., 2009).

Providing HPDs can be a useful intervention for low-income employees (Omokhodion et al., 2007), particularly in developing countries where HPD usage is low (Ologe et al., 2005; Omokhodion et al., 2007; Solanki et al., 2012). In addition to the direct benefits of HPD use, supplying HPDs has been widely-suggested as a means of increasing awareness of the risks and consequences of OHL (Edward et al., 2016). HPD usage has been found to increase where employees are aware of the level of noise to which they are been exposed (McTague et al., 2013), but unrelated to the employee's self-perceived level of risk, or their understanding of the consequences of hearing loss (Arezes & Miguel, 2005; Ologe et al., 2005; Zander & Richter, 2008).

Often HPDs are used exclusively, rather than in addition to, engineering and administrative control strategies (Arezes & Miguel, 2005; Daniell et al., 2006; Marlenga et al., 2012). In some industries like construction, this is owing to HPD usage being the only feasible intervention strategy available.

HPD usage tends to be highest in locations where the HCP is the most complete (Daniell et al., 2006; Hong et al., 2016). This means that other interventional strategies such as monitoring, engineering or administrative controls are also being employed. When measuring the level of HPD use at a worksite, self-reported measures tend to over report HPD use and the accuracy of self-reported data tends to decline over time (Griffin et al., 2009).

The effectiveness of HPDs varies widely and is dependent upon many different variables. Barriers to usage can be divided into categories of individual barriers and environmental barriers (Patel et al., 2001). Individual barriers to HPD use include personal attitudes and beliefs towards HPDs – considered to be a strong predictor of HPD use (Edelson et al., 2009; Halevi-Katz et al., 2015; Quick et al., 2008). Employees are more likely to consistently wear hearing protection once they have noticed a decline in their hearing (Hwang et al., 2001), or other OHL-related symptoms such as tinnitus (Voaklander et al., 2009). Employees may not use HPDs if they dislike the effect HPDs have on environment sounds (Halevi-Katz et al., 2015; Huttunen et al., 2011; Jansen, Helleman, schler, & Laat, 2009; Voaklander et al., 2009). HPDs are often seen as inconvenient while force of habit (not to use HPDs) and laziness are often described by workers as reasons for inconsistent HPD use (Gates & Jones, 2007). Individuals may also feel that hearing loss is an acceptable risk of their occupation, leading to poor HPD use (Hong et al., 2008).

Environmental barriers to HPD use include a lack of availability or difficulty locating HPDs when they are required (Gates & Jones, 2007; Ologe et al., 2005). HPDs have a negative effect on situational awareness and directionality (Clasing & Casali, 2014; Morata et al., 2005; Simpson et al., 2005). This can lead to interference with important work-related communication (

Hong et al., 2008; Jansen, Helleman, Schler, & Laat, 2009; Morata et al., 2005), and may cause safety concerns for the employee (Hong et al., 2008; Morata et al., 2005).
These communication and safety implications are more evident with individuals who suffer from a hearing loss (Morata et al., 2005).

Ensuring that HPDs are fit for the purpose they serve is an important consideration in the prevention of OHL (Rabinowitz et al., 2007; Themann et al., 2015). Fit is vital in ensuring that noise exposure is being reduced as much as possible, and employee comfort is crucial to improving HPD use. There is a lack of awareness about different types of HPDs available such as those with flat-attenuation or communication headsets (Morata et al., 2005). Level-dependent HPDs have been shown to preserve speech intelligibility whilst providing protection from impulse noise (Norin et al., 2011; Tufts et al., 2011; Williams, 2011). Level-dependent HPDs have been proven to be beneficial in increasing HPD wear time by affecting environmental sound to a lesser-degree during quiet periods, while still providing protection from loud, intermittent sound (Williams, 2011).

5.9 Outcome Measures

The results of this study have shown that it is possible to utilise a wide variety of outcome measures to examine different aspects of OHL. Although by far, the most common outcome measures in use involved measuring direct changes in hearing acuity through audiometry or changes in otoacoustics emissions, other studies utilised subjective means to evaluate changes in hearing such as self-reported symptoms of hearing loss and associated symptoms such as tinnitus or hyperacusis.

In addition to outcome measures looking at hearing-related changes on an individual level, some studies looked instead at the overall prevalence of hearing problems within the population. Reported numbers of AAT accidents, incidences of diagnosed OHL, and overall number of tinnitus and hyperacusis complaints are examples of this type of outcome measure. Rather than looking at changes in hearing, other studies assessed changes in preventative actions. This was measured via the amount of HPD use, or changes in the daily noise exposure of employees.

Finally, a number of studies used outcome measures that assessed the secondary effects of occupational noise exposure. These outcome measures varied widely depended on the goals of the researchers, and included measures of blood pressure, falls in the elderly, work readiness and the number of occupational injuries.

5.10 Study Locations

The vast majority of studies that met the inclusion criteria for either of the reviews were conducted within the United States of America. However, large clusters of studies ($n > 4$) were also found to have been performed in Australia, the United Kingdom, Sweden, Iran and Finland. Overall, the majority of sources concerning OHL were from developed countries. With the exception of Iran, all of the countries that produced large clusters of studies were located in what is traditionally considered the western hemisphere. The distribution of study locations can be seen below in figure 3.

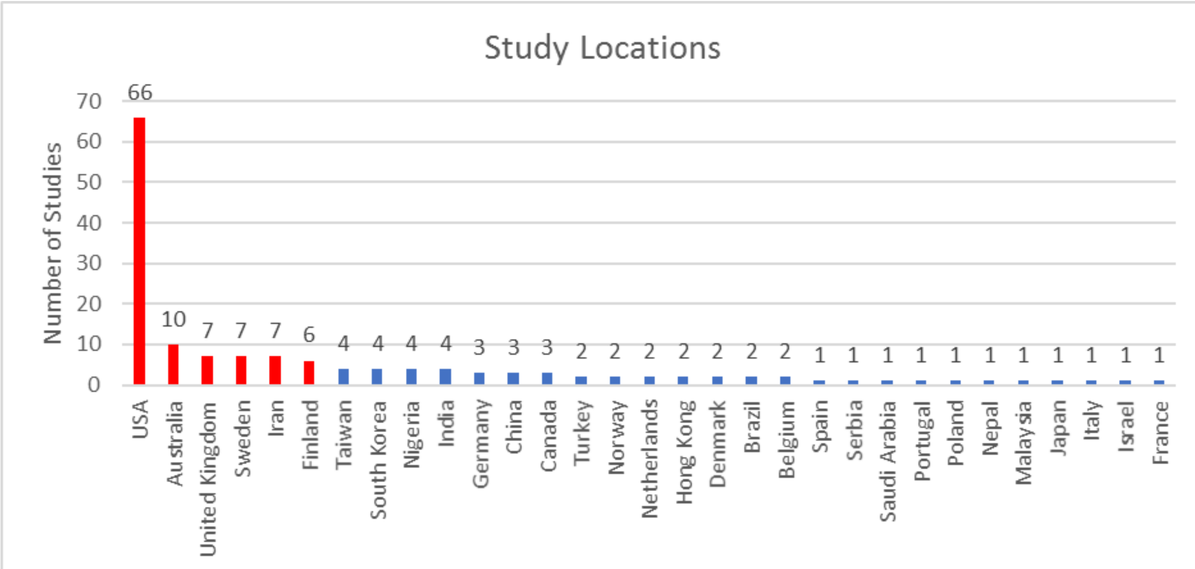

Figure 3: Studies by geographical location.

5.11 Study Limitations

This study was limited by its scope. Only one database was used to locate sources and only a small number of the located sources were screened due to the restrictions of the Multisearch software. This likely caused a lot of sources that would have met the inclusion criteria to be missed.

As sources were limited to English language due to the author's fluency, many articles that would have otherwise met the inclusion criteria of the study were rejected. This may have been the reason the majority of studies came from western-developed nations. If additional languages had been also accepted it may have addressed this bias and allowed for a more accurate representation of OHL on a global scale.

Finally, due to the nature of the scoping review framework articles that met the inclusion criteria were not assessed for the quality of their methodology. This means that there is no clear idea whether the sources used in this study are free of methodological or researcher bias.

5.12 Recommendations for Future Research

This study has shown the need of additional research into several different areas of OHL. These include research into the effects of prolonged noise exposure at levels below 85dBA, the most efficient way to tailor educational interventions to benefit individual employees, and research assessing the efficacy of different types of engineering controls.

Regarding the outcomes of this study, researchers may wish to expand on the scope of the study, assessing articles from additional databases and expanding the eligibility criteria to include articles written in languages other than English. This may provide a more nuanced view of the topic on a global scale.

Future researchers may wish to further evaluate the effectiveness of the interventions highlighted in this study. This could be achieved by pairing appropriate outcome measures from the second scoping review with the intervention of choice, using a systematic framework to analyse the article for any bias, and review the results. A systematic review of this type would allow for a more in-depth analysis of a narrowly-defined topic and provide more definite conclusions into how effective certain interventions are in the workplace.

In conclusion, this study has provided a roadmap for future research into the prevention of OHL. It is hoped that by illuminating the intervention strategies currently in use, and the outcome measures relevant to their assessment the effects of this preventable hearing loss may be reduced and the burden of OHL to both the individual and to society may be lessened.

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